1.0 PURPOSE AND NEED FOR THE LICENSE APPLICANT'S PROPOSED ACTION

1.1 INTRODUCTION

This Draft Environmental Assessment (EA) evaluates the potential environmental effects of this project pursuant to Executive Order (E.O.) 12114 on the Environmental Effects Abroad of Major Federal Actions, whose implementation is guided by the National Environmental Policy Act (NEPA) of 1969, as amended (42 United States Code (U.S.C). § 4321 *et seq*.), and the implementing regulations of the President's Council on Environmental Quality (CEQ; 40 Code of Federal Regulations (CFR) 1500-1508). This document incorporates by reference a prior EA prepared by the Federal Aviation Administration (FAA) dated and referred to as the February 11, 1999 EA, and is included as Appendix A of this document.

The proposed Federal action is to issue a launch operator license (LOL), and a launch-specific license for the Galaxy IIIC mission or other launch-specific licenses should the launch operator license be delayed or not issued, as described in Section 1.2. The purpose of the license applicant's proposed action is to fulfill the mandate of 49 United States Code (U.S.C). Subtitle IX – Commercial Space Transportation, ch. 701, Commercial Space Launch Activities, 49 U.S.C. §§ 70101-70121 and is more fully described in Section 1.3. The need for the license applicant's proposed action is also described more fully in Section 1.3. Section 1.4 presents, briefly, the background of the project, including the Federal government role, prior environmental analyses and documents, and public involvement. That section concludes with a roadmap for the remainder of this EA.

1.2 PROPOSED FEDERAL ACTION

The Federal action is for the FAA, Office of the Associate Administrator for Commercial Space Transportation (AST) to issue an LOL to Sea Launch Limited Partnership (SLLP) that would authorize SLLP to conduct launches from one launch site, within a range of launch parameters, of specific launch vehicles, transporting specified classes of payload. (See 14 CFR. 415.3(b)). The proposed LOL would authorize SLLP to:

- Conduct up to eight launches per year over a five-year period, for a maximum of 40 launches;[a]

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[a] Even under an LOL, a license applicant must provide the FAA with launch specific information. This will permit the FAA to have continuing oversight over SLLP operations. See 14 CFR 415.73 Continuing Acceptance of License Applications; Application for Modification of License. In accordance with 14 CFR 415.79, not later than 60 days before each flight conducted under a launch operator license, a licensee shall provide the FAA the following launch specific information:

1. payload information contained in 14 CFR 415.59;
2. flight information, including launch vehicle, planned flight path, including staging and impact locations, and on-orbit activity of the launch vehicle including payload delivery point(s); and
3. mission specific launch waivers, approved or pending, from a federal launch range from which the launch will take place, that are unique to the launch and may affect public safety.

Not later than noon, eastern standard time (EST), 15 days before each licensed flight a licensee shall submit to the FAA a completed Federal Aviation Administration/U.S. Space Command (FAA/USSPACECOM) Launch Notification Form (Office of Management and Budget (OMB) No. 2120-0608).

- Use a launch site at 0° latitude and 154° W longitude;
- Launch along a range of azimuths from 82.6° to 97.4°, inclusive[b];
- Use a Zenit-3SL launch vehicle; and
- Transport specified classes of payloads.

Any change to these LOL parameters would require additional environmental and safety analyses.

The FAA is also evaluating the possibility of issuing a launch-specific license to SLLP for the launch of Galaxy IIIC, as well as other potential launch-specific licenses (not to exceed eight per year) as necessary should the proposed LOL not be issued or be delayed. The proposed launch-specific licenses would authorize the SLLP to conduct specific launches:

- From a launch site at 0° latitude and 154°W longitude;
- On a launch azimuth within a range from 82.6° to 97.4°, inclusive;
- Using a Zenit-3SL launch vehicle; and
- Transporting specified classes of payloads.

The launch site location, launch vehicles, and classes of payloads that would be authorized under the proposed launch-specific licenses would be identical to the launch site location, launch vehicles, and classes of payloads that would be authorized under the proposed LOL. In addition, the launch azimuths that would be authorized under the launch-specific licenses would fall within the launch azimuth range that would be authorized under the LOL. Finally, the number of launch-specific licenses that would be issued per year would not exceed the number of the launches that would be authorized annually under the LOL (i.e., eight per year). The conduct that would be authorized under the proposed LOL and launch-specific licenses is identical, only the license application process would differ. Therefore, discussions and analyses of potential environmental impacts of the LOL and the launch-specific licenses are addressed together. Throughout the document, when the license applicant's proposed action is discussed, while emphasis is placed on the launch operator license, it should be understood that the launch-specific licenses are included in the license applicant's proposed action.

To obtain a launch license (either launch-specific or a launch operator license), an applicant must obtain policy and safety approvals from the FAA. Requirements for obtaining these approvals are contained in 14 CFR 415 Subpart B (Policy Review and Approval), Subpart C (Safety Review and Approval for Launch From a Federal Launch Range, including the calculation of acceptable flight risk), and Subpart F (Safety Review and Approval for Launch From a Launch Site not Operated by a Federal Launch Range). Other requirements include payload determination (14 CFR 415 Subpart D), financial responsibility (14 CFR 415.83, Subpart E) and environmental review (14 CFR 415 Subpart G).

A launch licensee shall report a launch accident, launch incident, or a mishap that involves a fatality or serious injury (as defined in 49 CFR 830.2) immediately to the FAA Washington Operations Center and provide a written preliminary report in the event of a launch accident or launch incident, in accordance with the accident investigation plan (AIP) submitted as part of its license application under 14 CFR 415.41.

[b] Within this range of azimuths, launches on azimuths of 83.28° to 84.50° have Impact Limit Lines (ILL) that overlay Cocos Island, 85.07° to 86.36° have ILL that overlay Malpelo Island, and 86.80° to 92.89° have ILL that overlay the Galapagos Island group. ILL are defined as the debris dispersion area where, with a statistical confidence of 99.67%, all the stages from successful flight as well as any material from a failure would impact. See Sections 2.3.4 and 2.3.5 below.

1.3 PURPOSE AND NEED FOR THE LICENSE APPLICANT'S PROPOSED ACTION

Access to space has become increasingly important for the deployment of satellites used for scientific research, communications, and multimodal transport navigation systems. Given the infrastructure and technology development costs associated with launching and deploying satellites, the Federal Government has been responsible for the majority of launches. However, with the increasing demand for access to space, especially for communications satellites, commercial launch companies have begun to offer launch services to meet this demand.

The purpose of the license applicant's proposed action as defined in 49 U.S.C. Subtitle IX – Commercial Space Transportation, ch. 701, Commercial Space Launch Activities, 49 U.S.C. §§ 70101-70121 is to:

- Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes;
- Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses;
- Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, safety of property, and national security and foreign policy interests of the U.S.; and
- Facilitate the strengthening and expansion of the U.S. space transportation infrastructure.

The need for the license applicant's proposed action is to streamline the FAA's licensing process while still assuring public safety and proper environmental review. Such a streamlined process will promote the entrepreneurial activity of a licensed launch provider. The proposed LOL would cover multiple launches using the same infrastructure at the same launch location through a range of launch azimuths without the need to re-evaluate license applications for individual launches unless there are changes in the license applicant's proposed action, environmental impacts or conditions of approval. The proposed LOL would allow SLLP to conduct up to eight launches per year for five years, for a maximum of 40 launches. The proposed LOL would allow SLLP to launch on exact equatorial azimuths (e.g., 90^o), which are optimal for geosynchronous orbit (GSO) launches in terms of fuel efficiency, payload weight, and satellite life span.

1.4 BACKGROUND

1.4.1 Federal Government Role

The purpose of 49 U.S.C. Subtitle IX – Commercial Space Transportation, ch. 701, Commercial Space Launch Activities, 49 U.S.C. §§ 70101-70121 is to promote, encourage, and facilitate the growth of the U.S. commercial space transportation industry. The U.S. Department of Transportation (DOT) was designated as the lead agency for licensing and regulating all U.S. commercial launch operations to ensure that they are conducted safely and responsibly. In November 1995, these responsibilities were delegated from the Office of the Secretary of Transportation to the FAA.

1.4.2 Prior Environmental Analyses

The FAA previously analyzed the environmental effects of licensed launch operations and launches in the Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986).

The Final Environmental Assessment for the SLLP Program dated February 11, 1999 (February 11, 1999 EA), described proposed launches and alternatives, the affected environment, potential environmental impacts, and environmental mitigation measures for the launches of one demonstration payload and one commercial satellite in the first year of operation, and six per year thereafter along a single launch azimuth. It included an Environmental Finding, which concluded that licensing the proposed launches was not a major Federal action that would significantly affect the quality of the human environment, and that preparation of an Environmental Impact Statement (EIS) was not required (see Appendix C). The FAA also prepared additional documents, including Written Reevaluations (WR) and findings, for two individual launches with azimuths that differed from that evaluated in the February 11, 1999 EA and for the use of UDMH and nitrogen tetroxide (N_2O_4) in the Upper Stage for Mission 6R (see Appendix D).

1.4.3 History of the License Applicant's Proposed Project

The SLLP project is an international commercial space launch project owned and operated jointly by Boeing Commercial Space Company of the United States, RSC Energia of Russia, KB Yuzhonoye and PO Yuzhmash of Ukraine, and Moss Maritime a.s. of Norway. The project's main assets are a seagoing mobile launch platform (LP), assembly and command ship (ACS), Home Port facilities in Long Beach, California, and the Zenit-3SL. The project is intended to place payloads in orbit from a launch site in the east central Pacific Ocean at 0° latitude and 154° W longitude.

On March 27, 1999, SLLP successfully completed its first demonstration payload launch (referred to as Mission 1), that confirmed the design and operation of the complete SLLP system. On October 9, 1999, commercial operations of SLLP officially began with the launch of DIRECTV 1-R, a direct broadcast satellite (Mission 2). Mission 3, for an ICO communication satellite, involved a nonequatorial launch azimuth (i.e., 135°) that was not evaluated in the February 11, 1999 EA. Therefore, a WR of the potential environmental effects of the launch along this azimuth was prepared for Mission 3 (see Appendix D). The WR findings were used by FAA in issuing a license for this mission. On March 12, 2000, SLLP launched the ICO communications satellite. Because of a malfunctioning propulsion valve, however, the flight was terminated before reaching orbit—approximately eight minutes after liftoff—by automatic on-board safety systems. On July 28, 2000, again using an equatorial launch azimuth as evaluated in the February 11, 1999 EA, SLLP successfully sent into orbit a PanAm Sat communications satellite (Mission 4). On October 21, 2000, SLLP successfully sent into orbit Thuraya-1, a mobile communications satellite (Mission 5). Because Mission 5 also involved an azimuth not evaluated in the February 11, 1999 EA (i.e., 83.28° rather than 88.67°), a WR was prepared to determine whether the license applicant's proposed action conformed to the plans and projects analyzed in the earlier EA; whether the data and analyses in the earlier EA were still valid; and whether all pertinent conditions and requirements of the prior approval were or would be met in the new action. The first attempted launch of XM-1, a radio communications satellite ended in a launch abort (Mission 6). This launch was successfully carried out on May 8, 2001 (Mission 6R). A WR was prepared for Mission 6R which addressed the impact of using 7 to 13 gallons of unsymmetrical dimethylhydrazine (UDMH) fuel along with N_2O_4 oxidizer, imported from Russia as the propellants for the Upper Stage (see Appendix E). On March 18, 2001, using an equatorial launch azimuth as evaluated in the February 11, 1999 EA, SLLP successfully sent into orbit XM-2, a radio communications satellite (Mission 7).

1.4.4 Relationship Between this EA and the February 11, 1999 EA

This document incorporates by reference the February 11, 1999 EA. The February 11, 1999 EA considered the license applicant's proposed action of issuing launch licenses for two SLLP launches, a demonstration launch carrying a simulated payload and a launch to deploy a satellite, and also considered the potential environmental impacts of up to six launches per year along the 88.67^o azimuth. The environmental impacts of specific launch licenses issued for launches along this azimuth were analyzed in the February 11, 1999 EA.

The license applicant's proposed action in this EA would use the Home Port facilities; conduct the same pre-launch operations; use the same launch vehicle and launch site (0° latitude and 154^{o}W longitude); and would conduct the same post-launch operations as evaluated in the February 11, 1999 EA. These aspects of the license applicant's proposed action are the same as those addressed in the February 11, 1999 EA. This EA incorporates by reference the February 11, 1999 EA, which is accessible at the FAA web site (http://ast.faa.gov) and is included as Appendix A of this document. This EA focuses on potential impacts of the license applicant's proposed action and the cumulative impacts of the launches that could occur as a result of issuing an LOL.

1.4.5 Public Involvement

The FAA issued a proposed Environmental Finding Document, finding no significant impact for the draft version of the February 11, 1999 EA, which was made available for public review from April 23 to May 26, 1998. The FAA also met with representatives of the Governments of Ecuador, Kiribati, Australia, and New Zealand, and with representatives of the South Pacific Regional Environmental Programme (SPREP). Additional meetings with representatives of SPREP and the Government of Ecuador have been held periodically to discuss upcoming launches and longer-term plans, such as the application for an LOL. A draft of this EA will be offered for public comment and announced in the U.S. *Federal Register*.

1.4.6 Roadmap for this EA

This EA is structured as follows:

- Introduction and description of the purpose and need for the license applicant's proposed action (Section 1.0).
- Description of the license applicant's proposed action and other alternatives, including No Action (Section 2.0).
- Description of the environment that could be affected by the license applicant's proposed action (Section 3.0).
- Evaluation of the environmental effects associated with the license applicant's proposed action and reasonable alternatives, including No Action (Section 4.0).

2.0 DESCRIPTION OF LICENSE APPLICANT'S PROPOSED ACTION AND ALTERNATIVES

2.1 SCREENING CRITERIA

For this EA, the FAA considered screening criteria to evaluate the license applicant's proposed action and reasonable alternatives to that action. The screening criteria are based on the purposes established in 49 U.S.C. Subtitle IX – Commercial Space Transportation, ch. 701, Commercial Space Launch Activities, 49 U.S.C.§70101-70121, as follows:

- To promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes.

- To encourage the United States private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance and transfer of commercial licenses; and facilitating and encouraging the use of Government-developed space technology.

- To provide FAA oversight and coordination of commercial launch activities and to protect the public health and safety, safety of property, and national security and foreign policy interests of the United States.

- To facilitate the strengthening and expansion of the United States space transportation infrastructure, including the enhancement of United States launch sites and launch-site support facilities, and development of reentry sites, with Government, State, and private sector involvement, to support the full range of United States space-related activities.

These criteria are applied in Section 2.6 to evaluate the reasonableness of the license applicant's proposed action and potential alternatives.

2.2 LICENSE APPLICANT'S PROPOSED ACTION

The license applicant's proposed action would be for the FAA to issue a launch operator license (LOL) to SLLP. The proposed license would authorize SLLP to:

- Conduct up to eight launches per year over a five-year period, for a maximum of 40 launches;
- Use a launch site at 0º latitude and 154º W longitude;
- Launch along a range of azimuths from 82.6º to 97.4º, inclusive[a];
- Use a Zenit-3SL launch vehicle; and
- Transport specified classes of payloads.

Any change to these proposed LOL parameters would require additional environmental and safety analyses.

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[a] Within this range of azimuths, launches on azimuths of 83.28º to 84.50º have Impact Limit Lines (ILL) that overlay Cocos Island, 85.07º to 86.36º have ILL that overlay Malpelo Island, and 86.80º to 92.89º have ILL that overlay the Galapagos Island group. Impact Limit Lines are defined as the debris dispersion envelope where, with a statistical confidence of 99.67%, all the stages from successful flight as well as any material from a failure would impact. See Sections 2.3.4 and 2.3.5 below.

The license applicant's proposed action would also include having the FAA issue a launch-specific license to SLLP for the launch of Galaxy IIIC, as well as other potential launch-specific licenses (not to exceed eight per year) as necessary should the proposed launch operator license not be issued or be delayed. The proposed launch-specific licenses would authorize the SLLP to conduct specific launches:

- From a launch site at 0° latitude and 154° W longitude;
- On a launch azimuth within a range from 82.6° to 97.4°, inclusive;
- Using a Zenit-3SL launch vehicle; and
- To transport specified classes of payloads.

The launch site location, launch vehicles, and classes of payloads that would be authorized under the proposed launch-specific licenses would be identical to the launch site location, launch vehicles, and classes of payloads that would be authorized under the proposed LOL. In addition, the launch azimuths that would be authorized under the launch-specific licenses would fall within the launch azimuth range that would be authorized under the LOL. Finally, the number of launch-specific licenses that would be issued per year would not exceed the number of the launches that would be authorized under the LOL per year (i.e., eight per year). The conduct that would be authorized under the LOL and launch-specific licenses is identical, only the license application process would differ. Therefore, discussions and analyses of potential environmental impacts of the proposed LOL and launch-specific licenses are addressed together. Thus, throughout the document, when the license applicant's proposed action is discussed, while emphasis is placed on the launch operator license, it is understood that the launch-specific licenses are included in the license applicant's proposed action.

The present Zenit-3SL configuration uses Russian-produced kerosene and liquid oxygen (LOX) for the propulsion of Stages I and II and the Upper Stage or Block DM-SL. Attitude control systems of the Upper Stage currently use a propulsion system of monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4). Other propellants that may be used during the five-year period covered by the LOL are also considered in the license applicant's proposed action. Specifically, unsymmetrical dimethylhydrazine (UDMH) is considered as a potential substitute for MMH in the Upper Stage attitude control system. The environmental consequences of this substitution are discussed in Section 4.1.1.3 (Sections 4.2.1.3 and 4.3.1.3 for alternatives) and Appendix E of this EA. UDMH and MMH are both hydrazine fuels (a type of launch vehicle and spacecraft fuel used in hypergolic propellant systems) that have different chemical and physical parameters (e.g., boiling point, specific gravity, vapor pressure, and flash point). The two fuels, however, are similar in terms of their reactivity, products of combustion (based on N_2O_4 as an oxidizer), exposure limits, and United Nations (UN) and United States Department of Transportation (DOT) hazard classification. The environmental consequences from the use of UDMH specific to the Upper Stage would be similar to those of MMH.

In addition, U.S.-produced kerosene or the Russian-produced kerosene substitute Boktan may be used instead of the Russian-produced kerosene for propulsion. Section 4.1.1.3. (Sections 4.2.1.3 and 4.3.1.3 for alternatives) and Appendix E of this EA compare these products. A full operational evaluation of Boktan has not yet been completed, but preliminary analysis indicates that physical and safety parameters of the three products are similar and the environmental consequences from the use of Boktan would be similar to those of both U.S. and Russian produced kerosene. Should SLLP decide to use Boktan at some point in the future, proper environmental analysis will be conducted as appropriate.

The commercial satellites to be launched—for telecommunication, observational, navigational, and scientific purposes—are propelled by systems employing hydrazine, MMH, N_2O_4, xenon ion propulsion, and/or electrical propulsion. Satellite systems are provided to SLLP fully contained (i.e., assembled, fueled and containerized) by the manufacturer.

Under the license applicant's proposed action and the other alternatives analyzed in this EA, each launch would involve maintenance and preparation of equipment at the Home Port in California, transit of the ACS and LP (with the launch vehicle onboard) to 0° latitude (on the Equator) and 154° W longitude, pre-launch preparations, launch and flight, and post-launch operations and monitoring. These procedures are briefly described in Sections 2.2.1 through 2.2.5.

2.2.1 Home Port

The Home Port is located on the former Long Beach Naval Station in Long Beach, California. The Home Port provides the facilities, equipment, supplies, personnel, and procedures necessary to receive, transport, process, test, and integrate the satellite payload and its associated support equipment with the launch system. It also serves as the home base for launch operations.

The three launch vehicle stages, the payload fairing, and the payload adapter are transported to the Home Port where they are processed, integrated with the spacecraft (forming the Integrated Launch Vehicle or ILV), and prepared for ocean transport. The ILV, personnel, and propellants (including kerosene and LOX) are transported onboard the LP and the ACS to the launch location. During transport to the launch site, the ILV electrical systems are checked and charged, and launch command processes and contingency measures are rehearsed.

The design, permitting, construction, and operation of the Home Port was evaluated in the February 11, 1999 EA (which addressed up to six launches per year, after the initial two launches). In preparing this EA, a verification of Home Port operations was conducted and several differences related to design, permitting and operation have been identified. This new information has been included in this document as Appendix B and updates the information in Appendices A and B of the February 11, 1999 EA, which is included in its entirety as Appendix A of this document.

The use of UDMH will not create new impacts from Home Port operations as SLLP will modify and comply with all Federal, State, and local permit requirements prior to UDMH arrival on-site. In addition, scrubber filters have been installed at the Home Port to prevent release of UDMH vapors.

The following documents need to be amended prior to UDMH arrival on-site at Home Port:

1. Hazardous Material Inventory Emergency Planning and Community Right to Know Act (EPCRA), Long Beach Department of Health, Certified Unified Program Agencies (CUPA)
2. Business Emergency Plan, Long Beach Fire Department
3. Operations Manual for the Transfer of Hazardous Material in Bulk, U.S. Coast Guard (USCG)
4. Integrated Contingency Plan, Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), California OSHA
5. California Offshore Emergency Service (COES), USCG

The following document will need to reflect the change in 2002:

1. Annual Emissions Inventory (Year 2001), South Coast Air Quality Management District (SCAQMD)

The following document will not require changes because thresholds are not exceeded:

1. Risk Management Plan, Long Beach Department of Health (CUPA)

Scrubber filter elements have been specifically designed, constructed, and delivered to SLLP to capture and neutralize vapors from UDMH. Following approval of the use of UDMH, these scrubbers will be installed at the SLLP facilities.

Substituting Russian Grade N_2O_4 for U.S. Grade N_2O_4 will not affect Home Port operations or permitting.

2.2.2 Pre-Launch

In the hours prior to launch, the LP is ballasted to a more stable, semi-submerged position. Pre-launch operations would involve only the final equipment and process checks, the coupling of fuel lines to the ILV prior to fueling, the transfer of kerosene and LOX fuels, and the decoupling of the fueling apparatus. All employees would be removed from the LP. The process would be remotely controlled from the ACS, located on the safety perimeter five kilometer (km) (three miles (mi)) away. Pre-launch operations are the same under the license applicant's proposed action as those described in the February 11, 1999 EA, Section 4.3.1.

2.2.3 Launch and Flight

Once the pre-launch preparations are complete, the launch and flight phase of the mission begins. The launch vehicle (the Zenit-3SL) uses kerosene and LOX as primary propellants. Prior launches have used Russian-produced kerosene for propulsion. U.S.-produced kerosene as well as a Russian-produced kerosene substitute called Boktan are being evaluated for future use. Testing will be conducted and if found suitable, these propellants may be used in future missions. Available data on Boktan, and U.S.-produced and Russian-produced kerosene are provided in Appendix E of this EA.

First-stage flight of the mission begins in international waters at 0° latitude and 154°W longitude and transits eastward over the equatorial Pacific Ocean. Stage and fairing separations occur as described in Table 2-1 and shown in Figure 2-1. The areas of stage and fairing deposition are outside the area included in the *Convention for the Protection for the Natural Resources and Environment of the South Pacific Region.* (See Section 4.1.1.2 of this EA for more detail.)

TABLE 2-1: IMPACT ZONES FOR STAGES AND FAIRING

Flight Element	Latitude (degrees)	Longitude (degrees)
Stage I	2 S to 2 N	147.7 W to 145.5 W
Fairing halves	2.2 S to 2.2 N	146.6 W to 142.2 W
Stage II	6 S to 6 N	116.6 W to 105.1 W

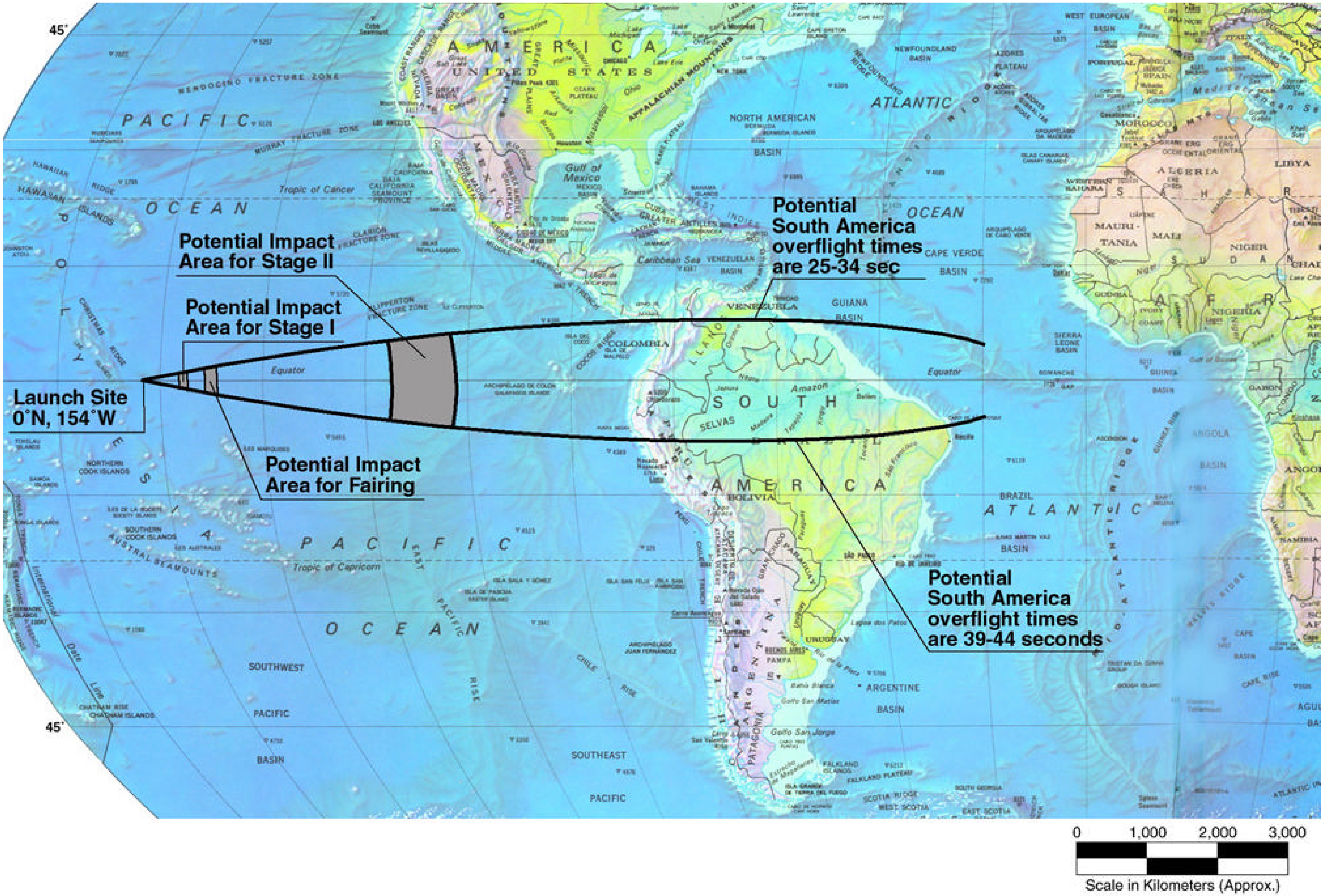
Based on the launch industry's experience with composite fairings, the two halves of the SLLP fairing would break up during descent and upon impact with the ocean surface. Prior SLLP launches have used a payload fairing with a 4.2 meter (m) (13.9 feet (ft)) diameter. This EA addresses the use of a larger fairing, up to 5.0 m (16.5 ft) in diameter, which would allow for maximum payload size and weight (Figure 2-1 and Table 2-1 are based on the 5.0 m fairing). Should SLLP propose to use a fairing larger than 5.0 m at some point in the future, proper environmental analysis will be conducted as appropriate. Under normal operating and contingency conditions, impacts from the stages and fairing would occur well outside the 200-nautical mile Exclusive Economic Zones (EEZs) of all countries in the area.

The Upper Stage begins powered flight over international waters and propels the satellite payload toward South America. Transit time across South America would range from 25 to 44 seconds (sec), depending on the azimuth of the launch. Once orbital, the Upper Stage separates from the payload, reorients, and executes an approximately 300 second burn to ensure that the Upper Stage does not affect the payload; this maneuver also provides for a safe storage orbit. MMH and N_2O_4 were used in all missions except 6R, which used UDMH and N_2O_4. Other materials may be used in the future after operational evaluation. Data on UDMH are provided in Appendix E of this EA.

The payload is moved and oriented into final position by its own propulsion system. The payloads use primarily hydrazine, MMH, UDMH, and N_2O_4 for propulsion. Other systems that may be used for propulsion, after evaluation and approval by FAA include xenon ion propulsion and electrical propulsion.

The release of any emissions from these later on-orbit maneuvers would occur well above the stratosphere and would not pose any significant environmental effects. Similarly, destruction of these propellants during a failure would be complete and incidental to the failure event.

Figure 2-1
Launch Operator License Groundtrack Corridor
(for 82.6 to 97.4 Launch Azimuths)



Source: Rand McNally, Atlas of the World.

Table 2-2 summarizes potential mission characteristics.

TABLE 2-2: POTENTIAL MISSION SUMMARY CHARACTERISTICS

Mission Element	*Characteristic*
Payload	Commercial satellite
Launch vehicle	Zenit-3SL
Launch site	0° latitude, 154° W longitude
Launch azimuth	82.6°to 97.4°, inclusive
Stages I, II, fairing impact zones	Deep and open ocean, limited vessel traffic, low biological productivity; *see Table 2-1 and Figure 2-1*
Overflight zone	Islands in eastern Pacific, including Galapagos Islands, Cocos Island, and Malpelo Island; portions of South and Central America

2.2.4 Post-Launch

After the launch, crews reoccupy the LP. In preparation for transit back to the Home Port, the crews collect any debris for examination, and subsequently wash and repaint the deck of the LP. The post-launch operations associated with the license applicant's proposed action are the same as that described in Section 4.3.3 of the February 11, 1999 EA. Debris would be disposed of in accordance with the International Convention for the Prevention of Pollution (in compliance with MARPOL 73/78) or brought back to Home Port for proper disposal. Monitoring activities are also conducted post-launch in compliance with the Environmental Monitoring and Protection Plan discussed in detail in Section 4.6.

2.2.5 Failure Scenarios

There are several possible failed mission scenarios considered in this EA:

- Explosion on the LP (impacts are discussed in Sections 4.1.2.1, 4.2.2.1, and 4.3.2.1 of this EA);
- In-flight failures of Stage I or Stage II (resulting from either an explosion or thrust termination) over the open ocean, (impacts are discussed in Sections 4.1.2.2, 4.2.2.2, and 4.3.2.2);
- In-flight failures of the Upper Stage (resulting from either an explosion or thrust termination) over the open ocean, Oceanic Islands, or South America (impacts are discussed in Sections 4.1.2.3, 4.2.2.3, and 4.3.2.3); and
- The cumulative failure of a number of launches in a single year along the same azimuth or azimuths in close proximity to one another (impacts are discussed in Sections 4.1.4.6, 4.2.4.6, and 4.3.4.6).

The failure scenarios, including multiple failures affecting the same area, generally involve the loss and return to Earth of some or virtually all of the ILV's components and hazardous materials.

This EA also addresses the scenario, in which the pre-launch process is interrupted moments before launch, resulting in a postponed or aborted launch. In this case, either the countdown is re-started, perhaps one to four days later, and the ILV is launched, or the ILV is stowed in the LP hanger, and the LP and ACS return to Home Port. While this scenario is not technically a failure, it is appropriate to consider possible effects to the environment from such an occurrence.

2.3 ALTERNATIVES CONSIDERED

This section discusses the alternatives to the license applicant's proposed action considered by the FAA and identifies reasonable alternatives considered in detail using the screening criteria described above in Section 2.1. For each alternative, unless otherwise stated, the Home Port, pre-launch, launch and flight, post launch, and possible failure scenarios will be the same as those described in Sections 2.2.1, 2.2.2, 2.2.3, 2.2.4, and 2.2.5, respectively. Alternatives that were previously considered in the February 11, 1999 EA, Section 2.2, are described in Section 2.4 of this EA.

Five alternatives to the license applicant's proposed action are identified for consideration in this EA. Each alternative still entails the proposed issuance of an LOL to SLLP (with the exception of the No Action Alternative). To this end, all aspects of each alternative (e.g., ILV and propellants) remain the same as the license applicant's proposed action except as specifically identified below.

2.3.1 Alternative Allowing up to 12 Launches Per Year

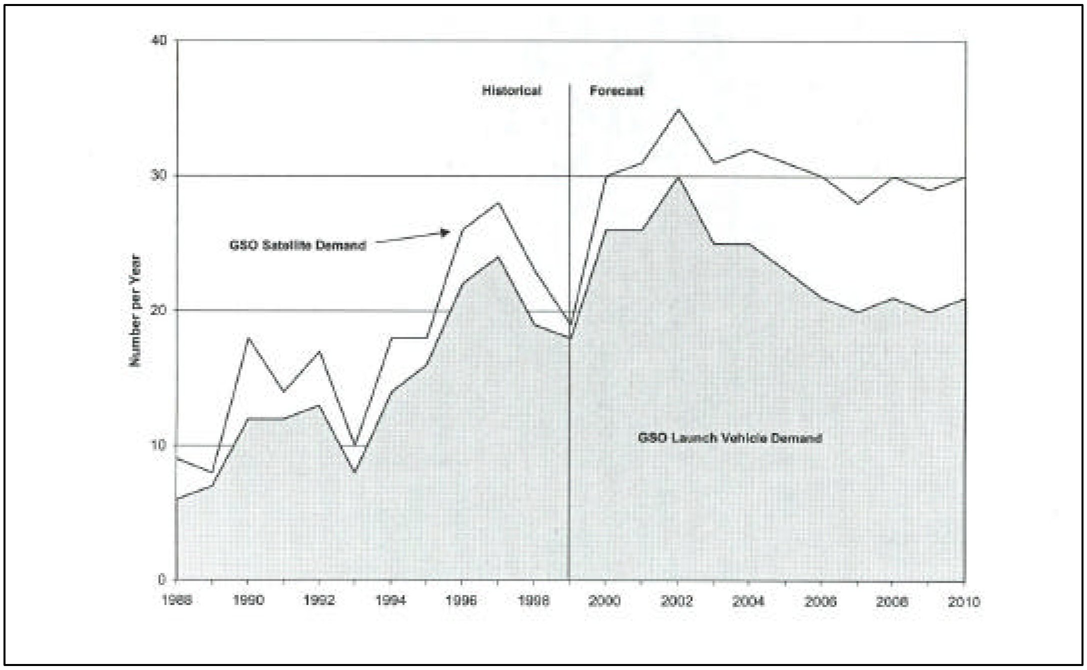
This alternative would involve the proposed issuance of an LOL to SLLP that would allow up to 12 launches per year as opposed to up to eight launches per year in the license applicant's proposed action.

The FAA and the Commercial Space Transportation Advisory Committee (COMSTAC) routinely evaluate the general market for satellite and launch demand. Figure 2-2 shows past launch data and the FAA's current projection of future demand for geosynchronous orbit (GSO) satellite launch services. As SLLP's launch system is particularly suited for launching heavy satellites, SLLP has identified GSO satellites to be the primary driver of its commercial operations.

As Figure 2-2 indicates, GSO launch vehicle demand is projected to range from 20 to 30 launches per year over the next decade. The FAA's market forecast for non-geostationary orbits (e.g., low-earth orbit (LEO), medium-earth orbit (MEO)) shows a major decline of proposed systems to be launched in non-geostationary orbits—a projected reduction of almost 40 percent (COMSTAC, 2000). Therefore, the FAA forecasts that most launches in the near future will be for GSO satellites.

SLLP has indicated that 12 launches per year was the most launches that it could reasonably be expected to conduct, based on operational considerations to date. All other aspects of this alternative (e.g., ILV and propellants) would remain the same as the license applicant's proposed action.

FIGURE 2-2: HISTORICAL AND FORECASTED DEMAND FOR GSO LAUNCHES



Source*: 2000 Commercial Space Transportation Forecasts*, Federal Aviation Administration's Associate Administrator for Commercial Space Transportation and the COMSTAC, May 2000.

2.3.2 Alternative with a Range of Azimuths Between 70^o and 110^o

This alternative would entail the proposed issuance of an LOL to SLLP with an increased range of azimuths from the 82.6^o to 97.4^o in the license applicant's proposed action to the 70^o to 110^o. All other aspects of this alternative (e.g., ILV and propellants) would remain the same as the license applicant's proposed action.

The range of possible azimuths is between 0^o and 360^o (i.e., the ILV theoretically could be launched in any direction from the launch site). Launches with azimuths between 180^o and 360^o would generally be going west or counter to the Earth's rotation and would therefore not be practical. Inclined azimuths (defined herein as 0^o to 70^o and 110^o to 180^o) would require extensive maneuvers of heavier satellites to move them into their final geosynchronous orbit. This would result in an increased transit time and fuel use, and pose an additional risk of failure or anomalies due to the required multiple firings of the Upper Stage to reach proper orbit. The increased risk of failures would likely cause orbital debris, which is hazardous to other spacecraft. Therefore, these azimuths are generally riskier, and are not considered feasible for GSO. Thus, only azimuths between 70^o to 110^o are a potentially feasible range of azimuths for GSO.

2.3.3 Alternative with Avoidance of National Parks and National Reserves

This alternative would involve the proposed issuance of an LOL to SLLP for the range of azimuths between 82.6^o to 97.4^o, but would require avoidance of specific azimuths within this range that would overfly any Nation's national parks or national reserves. There are 31 national parks or national reserves—five of which are on the UNESCO World Heritage Site List (Hammond, 1996; UNESCO, 2001) that could be potentially affected by launches in the proposed range of azimuths. The following azimuths would not require a direct launch vehicle overflight of a national park or a national reserve:

- 85.50º to 85.67º
- 92.90º to 93.25º
- 93.83º to 94.75º
- 96.68º to 97.40º

If ILL were considered, no azimuth in the range of 82.6º to 97.4º would be permissible under this alternative. All other aspects of this alternative (e.g., ILV and propellants) would remain the same as the license applicant's proposed action.

2.3.4 Alternative with Avoidance of the Oceanic Islands

This alternative would involve the proposed issuance of an LOL to SLLP for the same range of azimuths as the license applicant's proposed action (i.e., 82.6º to 97.4º), but would require avoidance of any azimuths that overfly any of the Oceanic Islands (i.e., Galapagos Islands, including the 40-mile marine sanctuary extending from all islands; Cocos Island; and Malpelo Island). The following azimuths would (see Figure 2-3) not involve overflight of any of the Oceanic Islands (including the ILL debris dispersion overlay)[b]:

- 82.60º to 83.28º
- 84.50º to 85.07º
- 86.36º to 86.80º
- 92.89º to 97.40º

Consequently, launches along azimuths ranging from 83.28º to 84.50º, 85.07º to 86.36º, and 86.80º to 92.89º would not be allowed under this alternative. All other aspects of this alternative (e.g., ILV and propellants) would remain the same as the license applicant's proposed action.

2.3.5 Alternative with Avoidance of the Galapagos Islands

This alternative would involve the proposed issuance of an LOL to SLLP for the same range of azimuths as the license applicant's proposed action (i.e., 82.6º to 97.4º), but would require avoidance of any azimuths that overfly the Galapagos Island group (including the 40-mile marine sanctuary extending from all islands). The following azimuths would (see Figure 2-4) not involve overflight of any of the Galapagos Islands (accounting for the ILL overlay)[Ibid.]:

- 82.60º to 86.80º
- 92.89º to 97.40º

Consequently, launch azimuths ranging from 86.80º to 92.89º would not be allowed under this alternative. All other aspects of this alternative (e.g., ILV and propellants) would remain the same as the license applicant's proposed action.

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[b] It should be noted that ILLs associated with an azimuth of 88.67º, in fact, would overlay Wolf and Darwin Islands of the Galapagos Island group. This azimuth was fully evaluated in the February 11, 1999 EA, and subsequent Environmental Finding and has been included in SLLP launch-specific licenses. Ibid.

2.4 PREVIOUSLY CONSIDERED ALTERNATIVES

The alternatives discussed below were considered in the February 11, 1999 EA, Section 2.2, and were eliminated from further consideration and analysis at that time.

2.4.1 Alternative Launch Vehicle

Two launch vehicles, the Zenit and the Cyclone, were available and considered viable candidates at the time the SLLP project was initiated (see Section 2.2.1 of the February 11, 1999 EA). During that consideration, the Cyclone's payload capacity was determined to be too small to handle projected customer demand. In addition, the Zenit launch vehicle system allows for horizontal integration, processing, and transport of the launch vehicle stages and payload, while the Cyclone launch vehicle does not. This feature was deemed essential for an ocean-based launch location because it would allow the ILV to remain in a safe and stable horizontal position during transport.

In addition to cost, efficiency, and market advantages, the Zenit and Upper Stage operating systems, staffing requirements, and propellant characteristics were considered favorable in terms of possible risk to SLLP operating personnel and the environment. Designing and producing a new launch vehicle, or procuring alternative assets from other launch system providers, were not considered commercially viable options. Furthermore, the integration of these alternative launch vehicles with other SLLP launch infrastructure had not been tested or proven safe and reliable.

Therefore, only the Zenit and Upper Stage satisfied all payload, operational, and safety criteria. The ACS and the LP have been configured to accommodate these systems.

The ACS and LP were designed to accommodate the Zenit-3SL. Due to engineering design requirements specific to the Zenit-3SL, the use of other launch vehicles on SLLP's ACS and LP is not feasible.

These considerations regarding the launch vehicle and Upper Stage remain valid for the license applicant's proposed action and alternatives in this EA.

Figure 2-3
License Applicant's Proposed Action with Avoidance of Oceanic Islands

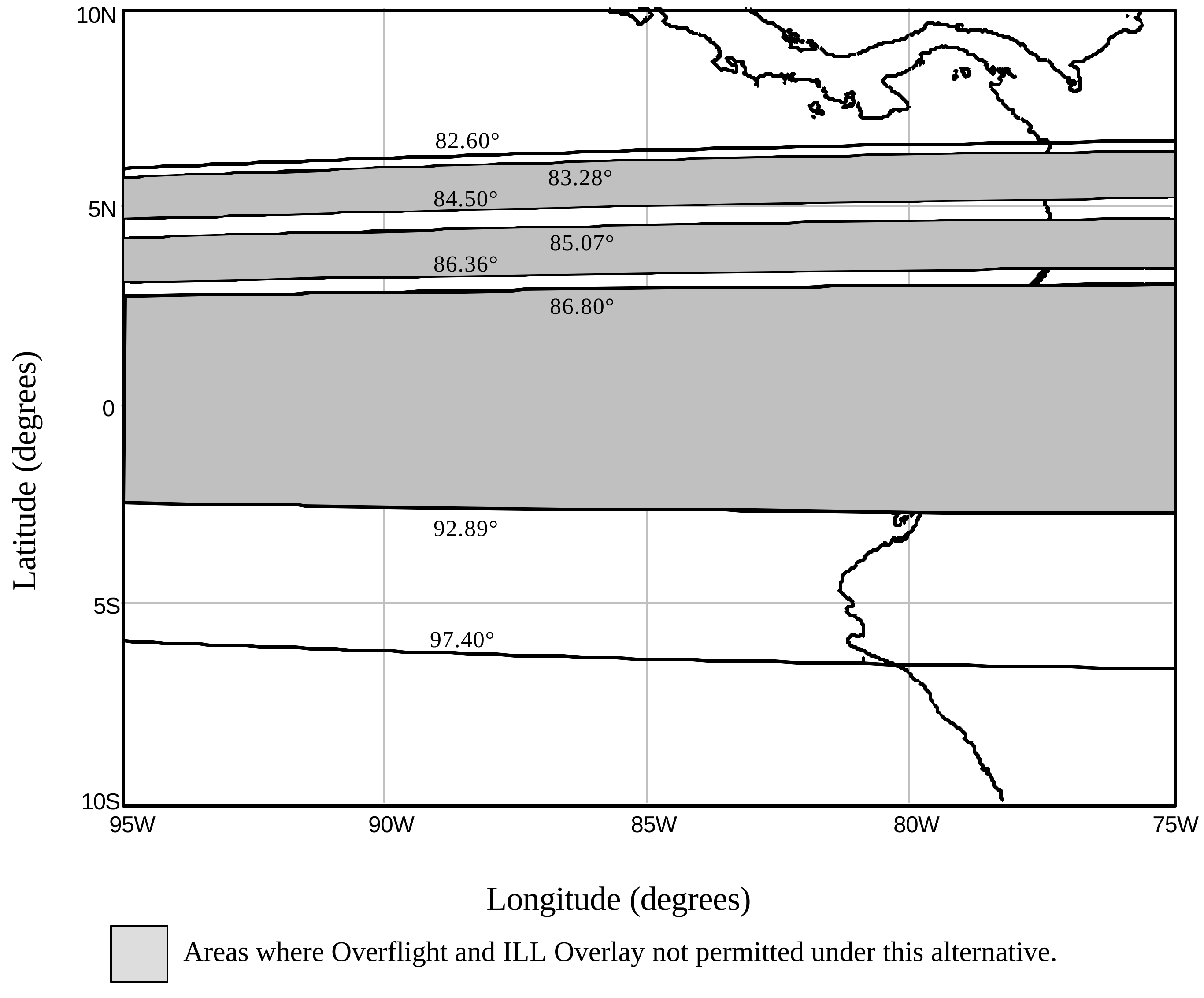
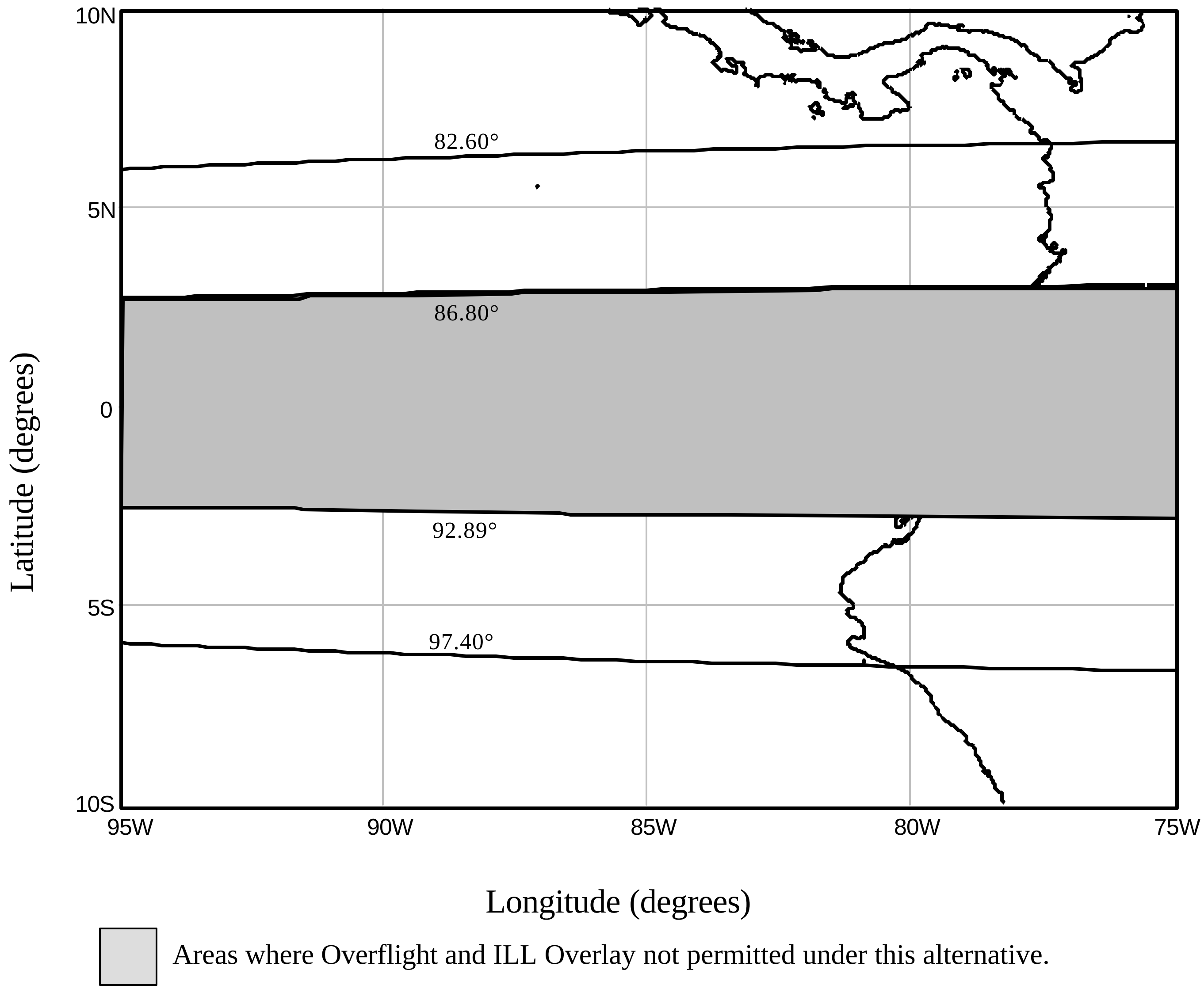


Figure 2-4
License Applicant's Proposed Action with Avoidance of Galapagos Islands



2.4.2 Use of an Alternative Launch Location

Alternative launch locations were previously considered by evaluating public safety, environmental protection, weather conditions, distance from commercial activities (e.g., fishing, recreation, shipping, and air traffic), and proximity to sovereign territories. It was concluded in the February 11, 1999 EA, Section 2.2.2, that these criteria indicated a launch location on the Equator in the east central Pacific Ocean would be most feasible.

For purposes of this EA, these criteria remain relevant and indicate a launch location at or near the Equator in the east central Pacific Ocean as optimal. The recommended launch site at 0° latitude and 154° W longitude is sufficiently distant from any populated areas (i.e., it is over 6,800 km [4,300 miles] from the Galapagos Islands, which are the closest inhabited areas along the flight path). This site was selected, in part, to ensure that spent stage and fairing deposition would only occur in the open ocean to minimize risk to human populations. The launch location also minimizes risk to wildlife populations that are similarly concentrated on land or in coastal waters.

2.5 NO ACTION ALTERNATIVE

Under the No Action alternative, the FAA would not issue an LOL for eight launches per year for five years, for a maximum of 40 launches, for azimuths from 82.6° and 97.4°, inclusive. Because SLLP is a foreign entity controlled by a United States citizen, it must obtain a launch license from the FAA. Thus, under the no action alternative, SLLP would need to continue to apply for launch-specific licenses for each proposed launch (up to six launch-specific licenses per year, or an average of one application every 60 days)[c]. For each proposed launch that would use an azimuth different from that considered in the February 11, 1999 EA, the FAA would need to consider the environmental effects and prepare the appropriate environmental documentation.

2.6 ALTERNATIVES EVALUATED DURING SCREENING PROCESS

2.6.1 Screening Methodology

The FAA completed a thorough and objective review of reasonable alternatives to the license applicant's proposed action. CEQ regulations require that an agency look at "reasonable" alternatives to the license applicant's proposed action. With that standard in mind, the FAA did not evaluate in detail those alternatives that showed no possibility of meeting the purpose and need of the license applicant's proposed action, as described in Section 1.3.

The screening methodology utilizes an evaluation process formulated to concentrate on the purpose and need for the license applicant's proposed action and the reasonableness of the alternatives. Alternatives that do not meet the purpose and need were eliminated from further consideration. Alternatives that meet the purpose and need were considered in detail. An evaluation of each alternative in terms of the screening criteria is provided below.

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[c] An individual who is a United States citizen or an entity organized or existing under the laws of the United States or any state must obtain a license to launch a launch vehicle outside of the United States or a license to operate a launch site outside of the United States. 14 CFR 413.3 (c).

2.6.1.1 License Applicant's Proposed Action

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* The license applicant's proposed action would promote entrepreneurial activity because it would provide a range of azimuths deemed necessary to meet predicted market demand for GSO launches. The ability to launch on a directly equatorial azimuth (i.e., 90º) would be unique worldwide and would offer commercial satellite customers a highly desirable launch option.

  A 90º azimuth is cost-effective and poses less risk of failure as it eliminates the need for maneuvers to remove orbital inclination. GSO satellites that are launched directly into an equatorial transfer orbit do not need to expend fuel to remove orbit inclination (they do however, expend some fuel, to raise their orbit to their final locations). Procedures associated with removing orbital inclination increase the time used by the satellite to reach its final orbit, by as much as a few weeks, resulting in additional cost and lost revenues for the satellite owner. The fuel expended to remove orbital inclination also shortens the useful life of the functioning satellite by approximately 10 to 15 percent for heavy payloads (Gailey, 2001). In addition, the maneuvers required to remove the orbital inclination of heavy payloads are more complex than those required to raise the orbit, and, therefore, increase the risk of an on-orbit anomaly or failure and orbital debris.

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* The license applicant's proposed action would encourage the private sector to provide launch vehicles and launch services by providing a long-term license that would simplify and expedite licensing. The issuance of an LOL would allow SLLP to conduct up to eight launches within specific launch parameters per year for five years. It would reduce the amount of time needed to prepare, submit and review license applications by allowing a more efficient licensing process while still assuring safety and environmental review.

  The option of issuing an LOL, as opposed to requiring a launch-specific license for every launch, provides advantages both to the FAA and the licensee. Although the resources spent to prepare and review an LOL application are likely to be greater than those required for a launch-specific license, this type of license will ultimately result in cost and schedule savings by reducing the number of applications that the FAA must review and that a commercial entity with an active launch schedule must submit. 64 Fed. Reg. 19,594, 19,595; Apr. 21, 1999.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* The license applicant's proposed action requires FAA oversight through the LOL licensing process, which includes both safety and environmental reviews. Additionally, pursuant to FAA regulations, SLLP will be required to notify the FAA of each specific launch and to provide launch-specific information should the FAA issue the proposed LOL (see14 CFR 415). Should any of the proposed LOL parameters change, the FAA would require additional environmental and safety documentation and analyses. The SLLP launch infrastructure and operating procedures to be used under the license applicant's proposed action have been successful in six missions to date. The FAA has closely monitored all missions and SLLP's operations have resulted in no health or safety issues and the results of the environmental monitoring program have confirmed that the environmental impacts of the earlier missions have been insignificant.

The license applicant's proposed action also is consistent with U.S. national security and foreign policy interests. Reliable access to space, as provided under the license applicant's proposed action, promotes U.S. national security. National Space Policy, Fact sheet, Space Transportation (Sept. 19, 1996). Moreover, the SLLP launch procedures incorporate U.S. Government approved national security safeguards. The proposed SLLP launches are consistent with U.S. treaty obligations, including the Convention for the Protection of the Natural Resources and Environment in the South Pacific Region (done November 24, 1986; entered into force August 22, 1990) and the Agreement Establishing the South Pacific Regional Environment Programme (done June 16, 1993; entered into force August 21, 1995).

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* The license applicant's proposed action strengthens and expands U.S. space transportation infrastructure by facilitating the use of an ocean-based launch site in addition to the traditional land-based U.S. Federal launch facilities. SLLP is the only equatorial launch site offered by a U.S. launch services provider. Thus, the license applicant's proposed action would expand U.S. space transportation infrastructure options for potential customers by providing an additional launch site choice.

The license applicant's proposed action satisfies all of the screening criteria and will, therefore, be analyzed in this EA. The license applicant's proposed action includes the possibility of the FAA issuing a launch-specific license to SLLP for the launch of Galaxy IIIC, as well as other potential launch-specific licenses (not to exceed 8 per year) as necessary should the proposed LOL not be issued or be delayed. The conduct that would be authorized under the proposed LOL and launch-specific licenses is identical, only the license application process would differ. Therefore, discussions and analyses of potential environmental impacts of the proposed LOL and the proposed launch-specific licenses are addressed together. Throughout the document, when the license applicant's proposed action is discussed, while emphasis is placed on the launch operator license, it is understood that the launch-specific licenses are included in the license applicant's proposed action.

2.6.1.2 Alternative Allowing up to 12 Launches per Year

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* This alternative would promote entrepreneurial activity by providing a range of azimuths sufficient to allow SLLP to meet projected market demand for GSO launches.

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* This alternative would encourage the private sector to provide launch vehicles and services in the same manner as the license applicant's proposed action discussed above.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* This alternative would be reviewed for safety purposes through the FAA's licensing process. Any changes to SLLP's operations would need FAA's approval (i.e., the FAA is the authority for commercial launch licenses and will not license any launch that does not demonstrate a requisite level of safety and required environmental review).

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* Although this alternative would appear on its face to expand U.S. space transportation infrastructure in that it would increase the use of an ocean-based launch site in addition to traditional land-based U.S. Federal and commercial launch facilities, SLLP does not currently have the infrastructure to support this schedule. SLLP currently does not have the infrastructure or operating procedures in place to support this level of launch activity without fundamental changes. For example, the LP would not have time to travel to and from the launch site to support an accelerated schedule. Thus, the turnaround time to process launches this frequently would require a transfer of the launch vehicle from the ACS to the LP somewhere near the launch site. This required change in infrastructure and operating procedures has not been examined; at this time, it is untested and has not been proven to be reliable or safe. Accordingly, this alternative, at this time, cannot facilitate the strengthening or expansion of U.S. space transportation infrastructure.

Therefore, this alternative has been dismissed because it does not meet all of the screening criteria.

2.6.1.3 Alternative with a Range of Azimuths Between 70° and 110°

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* This alternative might promote entrepreneurial activity by permitting more azimuths than were contemplated under the license applicant's proposed action in addition to permitting the range of azimuths between 82.6° and 97.4°.

  However, entrepreneurial launch activity, such as the SLLP project, will be promoted only to the extent that customer demand exists for the proposed launch services. The commercial launch industry is driven by the demands of satellite manufacturers and owners for the cost-effective delivery of the satellites to specific and well-defined orbits that are useful for the services that their companies provide. Accordingly, it is critical for launch service providers to provide service offerings that meet market requirements. At this time there appears to be limited demand projected for launches at slightly inclined attitudes, i.e., ranging from 70° to 82.6° and 97.4° to 110°. Therefore, because no market exists for this alternative, it does not meet the intent of promoting economic growth.

  In addition, this alternative would—for certain azimuths—require additional fuel expenditures and potentially risky on-orbit maneuvers that could lead to other problems (e.g., failures with increased orbital debris). The use of certain slightly inclined azimuths would require extensive, additional maneuvers to move satellites into their final GSO. Procedures associated with removing orbital inclination increase the time used by the satellite to reach its final orbit, by as much as a few weeks, resulting in increased cost and lost revenues for the satellite owner. The fuel expended to remove orbital inclination also shortens the useful life of the functioning satellite by approximately 10 to 15 percent for heavy payloads (Gailey, 2001). This alternative would not promote economic growth and entrepreneurial activity in the same manner as the license applicant's proposed action.

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* This alternative would encourage the private sector to provide launch vehicles and services in the same manner as the license applicant's proposed action.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* This alternative would be reviewed for safety purposes through the FAA's licensing process.

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* This alternative would strengthen and expand the U.S. space transportation infrastructure to the same extent as the license applicant's proposed action.

This alternative would not promote economic growth and entrepreneurial activity for all the azimuths in the proposed range. Further, the additional maneuvers required to move satellites into their final GSO, while they are not as extreme as for a fully inclined azimuth (see Section 2.3), would still increase risk of a failure or anomaly. Such a failure or anomaly could create orbital debris. Moreover, this alternative would not provide advantage to commercial customers beyond the license applicant's proposed action. Consequently, this alternative was not evaluated further.

2.6.1.4 Alternative with Avoidance of National Parks and National Reserves

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* This alternative would promote entrepreneurial activity through the use of space for peaceful purposes. However, it involves a restricted range of azimuths compared to the license applicant's proposed action that would limit commercial flexibility to meet market demand. Avoiding overflights of all national parks and reserves within the azimuth range of 82.6º to 97.4º would only leave 2.16º of the range available for commercial use. There are no potential azimuths in the 82.6º to 97.4º range that would avoid concern regarding national parks and reserves when ILLs are taken into account.[d]

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* Issuing an LOL to allow SLLP to conduct up to eight launches per year for five years, would simplify and expedite commercial launch licensing. However, an LOL for such a narrow range of azimuths would mean that SLLP would still have to obtain a launch-specific license for each launch along any azimuth outside the narrow range identified that would avoid overflights.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* This alternative would be reviewed for safety purposes through the FAA's licensing process.

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* This alternative would strengthen and expand the U.S. space transportation infrastructure to the extent that it would provide for the use of an ocean-based launch site in addition to traditional land-based U.S. Federal launch facilities.

This alternative does not meet the screening criteria, is not considered feasible and will not be evaluated further in this EA. The restricted range of azimuths compared to the license applicant's

[d] It should be noted that FAA has licensed other SLLP missions where the ILLs overlay environmentally sensitive areas.

proposed action that would limit commercial flexibility to meet market demand. The narrow range of azimuths proposed under this alternative would severely restrict commercial operations and would not simplify or expedite the FAA's licensing of commercial launches.

2.6.1.5 Alternative with Avoidance of the Oceanic Islands

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* This alternative would promote entrepreneurial activity in that it would provide a range of azimuths sufficient for SLLP to meet a portion of the projected GSO launch market demand. However, this alternative would preclude azimuths that require overflight of the Galapagos Islands, Malpelo Island and Cocos Island, and therefore GSO launches would require limited maneuvers with some risk involved, to remove orbital inclination. These maneuvers would further require additional fuel consumption and transit time for the payload to reach its final orbit. While this is not optimal, it would still allow a range of azimuths and provide for greater opportunity for entrepreneurial activity than SLLP's currently authorized operations.

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* This alternative would encourage the private sector to provide launch vehicles and services through a simplified and expedited licensing procedure. This proposed alternative would involve the issuance of an LOL that would allow SLLP to conduct up to eight launches per year for five years for the general range of azimuths identified in the license applicant's proposed action with the exception of those azimuths that would require overflight of the Galapagos Islands, Malpelo Island, and Cocos Island. Such an LOL would relieve SLLP of having to apply for individual launch-specific licenses along the approved azimuth ranges in the LOL, thus simplifying and expediting the licensing process. SLLP would still have to pursue launch-specific licenses for proposed launches along any azimuth outside this range.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* This alternative would be reviewed for safety purposes through the FAA's licensing process.

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* This alternative strengthens and expands U.S. space transportation infrastructure in the same manner as the license applicant's proposed action.

This alternative, even though not optimal from an operating flexibility standpoint, satisfies the screening criteria and is therefore considered a reasonable alternative to analyze in this EA.

2.6.1.6 Alternative with Avoidance of the Galapagos Islands

- *Promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes:* This alternative would promote entrepreneurial activity in that it would provide a range of azimuths sufficient for SLLP to help meet most projected GSO launch market demand. This alternative would preclude azimuths that require overflight of the Galapagos Islands, and therefore GSO launches would require limited maneuvers with some additional risk, to remove orbital inclination. These maneuvers would require additional fuel consumption and transit time for the payload to reach its final orbit.

- *Encourage the U.S. private sector to provide launch vehicles, reentry vehicles, and associated services by simplifying and expediting the issuance of licenses:* This alternative would encourage the private sector to provide launch vehicles and services through a simplified and expedited licensing procedure. This proposed alternative would involve the issuance of a LOL that would allow SLLP to conduct up to eight launches per year for five years along a range of azimuths similar to the license applicant's proposed action but excluding those requiring overflight of the Galapagos Islands. This alternative would relieve the license applicant and the FAA from conducting the launch-specific license application process for proposed launches within the LOL-specified azimuth ranges.

- *Provide FAA oversight and coordination of licensed launches and to protect the public health and safety, the safety of property, and U.S. national security and foreign policy interests of the U.S.:* This alternative would be reviewed for safety purposes through the FAA's licensing process.

- *Facilitate the strengthening and expansion of the U.S. space transportation infrastructure:* This alternative would strengthen and expand the U.S. space transportation infrastructure in the same manner as the license applicant's proposed action discussed above.

This alternative, even though not optimal from an operating flexibility standpoint, satisfies the screening criteria and is therefore considered a reasonable alternative to analyze in this EA.

2.6.2 Alternatives Studied in Detail

Based on the screening process described above, three alternatives are identified as reasonable (i.e., satisfy the screening criteria defined in Section 2.1) and are evaluated in detail in this EA. These alternatives are:

- License applicant's proposed action – issuance of a LOL for up to eight launches per year for five years with launch azimuths between 82.6° and 97.4° and a launch-specific license for one mission with a launch azimuth of 90° (Galaxy IIIC);
- Alternative with avoidance of the Oceanic Islands; and
- Alternative with avoidance of the Galapagos Islands.

Based on the requirements of E.O. 12114 as guided by NEPA, the EA also evaluates the No Action alternative.

Each of these alternatives is evaluated in Section 4 of this EA.

3.0 AFFECTED ENVIRONMENT

3.1 OVERVIEW

Under the license applicant's proposed action and the alternatives, all launches would originate from the SLLP LP in the Pacific Ocean, 425 km (266 mi) southeast of Kiritimati (Christmas) Island of the Kiribati Island Group, at 0° latitude and 154° W longitude. The launch location is the same as described in Sections 2.1 and 3.0 of the February 11, 1999 EA (see Appendix A). This EA discusses the area potentially affected by the license applicant's proposed action and the reasonable alternatives to that action.

For purposes of this EA, the affected environment is based on an area defined on and above the Earth's surface by the proposed azimuth range of 82.6° to 97.4°. The affected environment would include the geographic area extending from the LP to the east coast of South America, beyond which the payload would be orbital and no further effects on land or water are expected to occur. The area potentially affected by the proposed launches includes all land, water, and the atmosphere between 7.4° N and 7.4° S of the equator and between the launch location and the eastern coast of South America (see Figure 3-1). This area encompasses approximately nine million km^2 (3.5 million mi^2) of the equatorial Pacific Ocean and five million km^2 (1.9 million mi^2) of South America. The vast majority of the marine area is deep, open portions of the Pacific Ocean, though the proposed range of flightpaths includes overflights of the Galapagos Islands, Cocos Island, and Malpelo Island. Further east, the area of the South American flyover encompasses several ecosystems, including Pacific coastal lowlands, the Andean mountain range, and much of the Amazon River basin.

In previous missions orbit parameters were known in detail, in advance, and were evaluated on a mission-specific basis, which included delineation of ILL. ILLs are based on a statistical analysis showing where, with greater than 99.67 percent certainty (i.e., based on three standard deviations or 3 σ), Zenit-3SL stages and debris from a failed mission would fall. In considering the potential impacts of possible failure scenarios, the ILLs for the outer most azimuths of the proposed 82.6° to 97.4° range have been calculated and are used to set the "boundaries" of the potentially impacted ocean and landmass areas given the range of potential missions that could be carried out under the license applicant's proposed action.

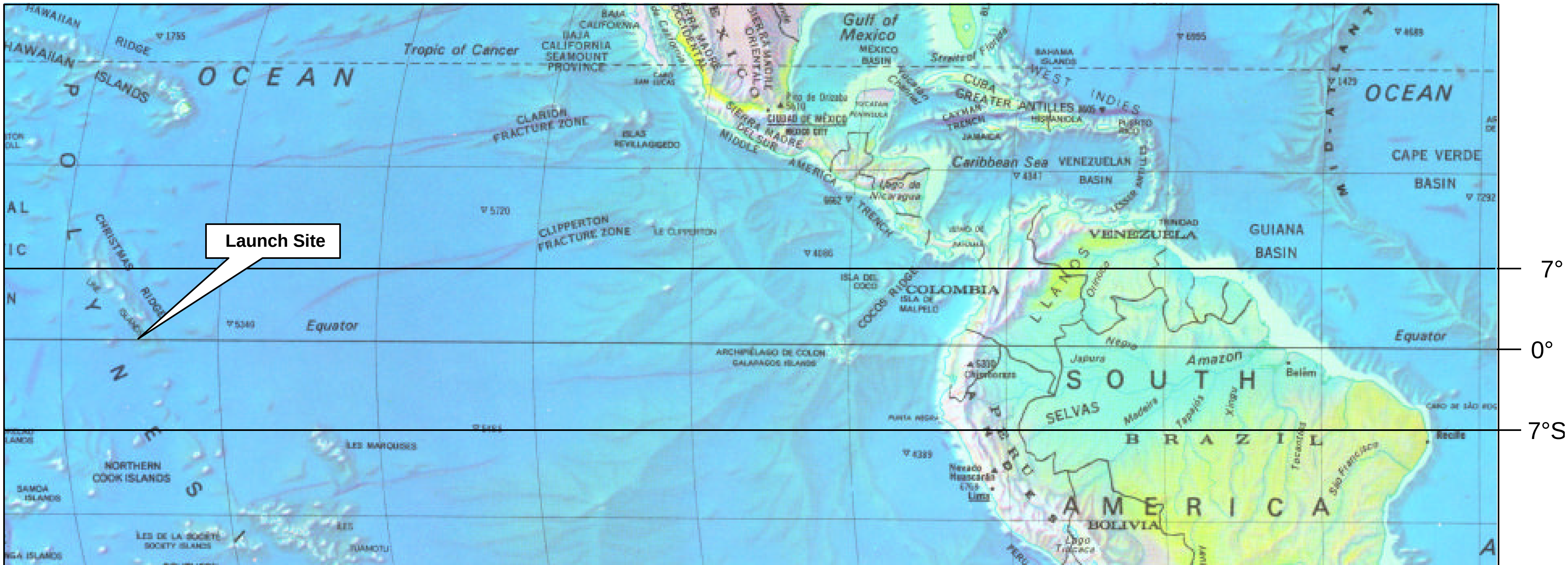
This section of the EA is organized according to geographic area and describes existing or baseline environmental conditions for the open ocean, Oceanic Islands, and continental South America. It should be noted that for the 83° azimuth, the ILL overlays a small portion of Central America; however, this landmass would not be overflown by the ILV and would only be potentially of concern given a failure of the Upper Stage as discussed in Section 4.

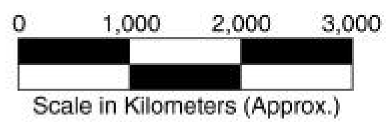
3.2 GEOGRAPHIC AREAS

3.2.1 Open Ocean

Approximately nine million km^2 (3.5 million mi^2) of open ocean are included within the affected environment. This section provides an overview of the geology, atmospheric processes, oceanography, biological communities, and commerce of the equatorial Pacific Ocean. Other aspects of the affected environment — such as visual resources, social conditions, and cultural

Figure 3-1
Affected Environment - From Launch Site to Eastern South America (7° north to 7° south)





Source: Rand McNally Atlas of the World.

resources — are not applicable because there are no human inhabitants of this area and it is the site of occasional commercial shipping or fishing.

3.2.1.1 Geology

The lithosphere in the equatorial Pacific region is broken up into roughly two dozen plates, which create various features on the ocean floor, such as ridges, trenches, and volcanoes. The region east of the launch location consists of three main tectonic plates: the Nazca Plate, moving east toward the South American Plate; the Cocos Plate, moving north; and the Pacific Plate, moving west. The Galapagos Spreading Center — also known as the Galapagos Rift — located just north of the Galapagos Archipelago, is a mid-ocean ridge formed by the edges of plates moving away from each other. The rift has a major transform fault located just north of the Galapagos Islands at 91° W. A major subduction zone, where the plates discussed above are colliding, is located along the west coast of Central and South America, and is marked by deep trenches and overlying chains of volcanoes (Clapperton, 1993). The movement of the Nazca Plate produced a chain of seamounts known as the Carnegie Ridge. A second seamount chain, the Cocos Ridge, extends northeast from the Galapagos Spreading Center (see Figure 3-2).

3.2.1.2 Atmospheric Processes and Conditions

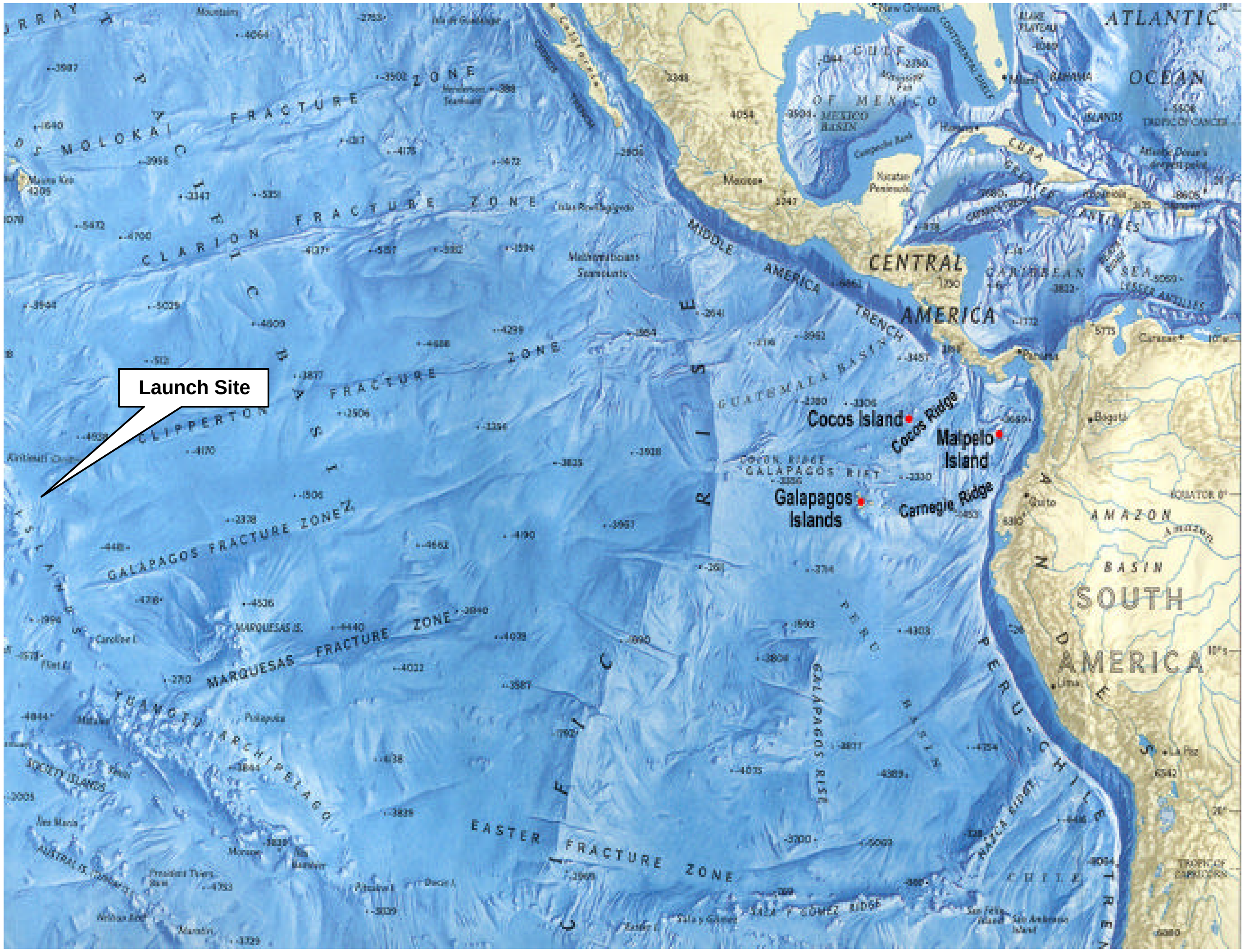
In the eastern portion of the Pacific, the atmosphere and ocean continually interact in physical and chemical cycles. Ocean surface temperatures play a large role in atmospheric conditions. A daily cycle of solar heat drives convective mixing. Convective mixing occurs as a result of changes in water stability, i.e., when surface water becomes denser than subsurface water an unstable condition exists. In this case the surface water sinks and the subsurface water rises to the surface thus creating a mixing effect. In addition, regional trade winds from the east push equatorial surface water into a mound in the west-equatorial Pacific Ocean which affects atmospheric conditions. For still unknown reasons, the trade winds occasionally weaken, causing a reverse flow of warm surface waters to the east which then mound against South America. The additional pressure of warm water in the east-equatorial Pacific Ocean inhibits and slows the upwelling of the more dense, cold, and nutrient-rich deep ocean water (Philander, 1992; and Lukas, 1992) in a phenomenon known as the El Nino/Southern Oscillation. The El Nino effect includes an extreme decline in ecosystem productivity along the coast of South America, and great fluctuations in heat transfer and molecular exchange between the ocean and the atmosphere throughout the Pacific region (Lukas, 1992). El Nino has little effect on ecosystem productivity in the ocean waters of the launch location and range.

It has been estimated that these processes in the equatorial Pacific region annually cycle 3×10^{11} kilogram (kg) (7×10^{11} pounds (lbs)) of carbon dioxide (CO_2) between the ocean and atmosphere, and about the same amount of particulate carbon settles to the deep ocean waters per year to be replaced by upwelling and the westward equatorial current. (Murray, 1994).

Atmospheric Layers

The atmosphere can be classified into five layers or strata. From the ocean moving upward they are 1) the atmospheric boundary layer or lower troposphere, 2) the free troposphere, 3) the stratosphere, 4) the mesosphere, and 5) the thermosphere (also called the ionosphere). The troposphere is the lowest part of the atmosphere and represents the portion Figure 3-2 of the atmosphere where the frictional effects of the Earth's surface may be substantial.

Figure 3-2
Ocean Floor of the Affected Environment



0 1000 2000

Scale in Kilometers (Approx.)

Source: National Geographic Society
Mercator Projection,

Note: Depths are in meters.

It extends from the surface to approximately 2 km (1.2 mi) above sea level, although the actual height is a function of surface roughness and temperature gradient.

The free troposphere is that portion of the atmosphere extending from the top of the atmospheric boundary layer to the bottom of the stratosphere. Exact elevations are a function of time and location, but for purposes of this analysis, can be taken to be approximately 2 to 10 km (1.2 to 6.2 mi). The free troposphere frequently receives polluted air from the atmospheric boundary layer and, less often, ozone from the stratosphere. Emissions to or entering the free troposphere are subject to photochemical oxidation and chemical reactions within cloud droplets. Most emissions that undergo such chemical reactions are returned to the atmospheric boundary layer or to the Earth's surface by precipitation. The thermal heat balance of the Earth's surface is due in great measure to the regulation of incoming and outgoing radiation by clouds and gases in the free troposphere.

The stratosphere is that part of the atmosphere from approximately 10 to 50 km (6.2 to 31 mi) above the Earth's surface. The temperature of the stratosphere rises from a minimum at its base to a maximum at its top. This increase in temperature is due to the increased absorption of ultraviolet radiation energy by ozone. The stratosphere is the main region of ozone production in the atmosphere, and this ozone plays a critical role in protecting the Earth's surface from ultraviolet radiation and in regulating the Earth's heat energy balance. It is estimated that approximately 3.5×10^8 kg (7.7×10^8 lbs) of ozone are formed and destroyed daily by natural processes in the stratosphere (Manahan, 1994). An ozone molecule is destroyed by the adsorption of ultraviolet radiation energy, which triggers a series of reactions that combine one oxygen atom with one ozone molecule. The destruction of the ozone layer is due in part to the placement of certain chemicals into the stratosphere, primarily as a result of human activities, that serve to catalyze these reactions leading to the destruction of ozone.

Above the stratosphere, the mesosphere extends from approximately 50 to 85 km (31 to 53 mi). Characteristic of the mesosphere is a drop in temperature with an increase in altitude, due to the absence of radiation adsorbing molecules. Above the mesosphere is the thermosphere where the temperature rises because of molecular adsorption of high energy solar radiation.

3.2.1.3 Baseline Noise Conditions

Baseline or ambient noise levels on the ocean surface—not including localized noise attributed to shipping—is a function of local and regional wind speeds. Studies of ambient noise of the ocean have found that the sea surface is the predominant source of noise, and that the source is associated with the breaking of waves (Knudsen, et al., 1948). Wave breaking is further correlated to wind speed, resulting in a relationship between noise level and wind speed (Cato, et al., 1994).

Typical wind speeds for the eastern portion of the Pacific Ocean range from 2 to 13.5 meters/second (m/s) (5 to 30 miles per hour (mph); National Imagery and Mapping Agency (NIMA), 1998, and Cato, et al., 1994). These wind speeds correspond to a noise level range of approximately 55 decibel (dB) to 68dB. At the launch location, the predominant wind speed throughout the year is approximately 8 m/s (18 mph) (NIMA, 1998). This wind speed corresponds to an ambient noise level of 64 dB. Moving eastward from the launch site to the Oceanic Islands, the dominant wind speed decreases from about 8 m/s to roughly 5 m/s (18 mph to 12 mph). Near the Oceanic Islands, the predominant wind speed is approximately 5 m/s

(12 mph) (NIMA, 1998), corresponding to an ambient noise level of 60 dB. Observed seasonal changes in winds usually do not include changes in wind speed but rather wind direction (NIMA, 1998). Storms and other weather events, however, would increase localized wind speed, and therefore would increase the noise level for the duration of that weather event.

3.2.1.4 Oceanography

Open ocean currents in the equatorial Pacific region are driven by the wind and rotation of the Earth (see Figure 3-3). Waters along the coast of South America flow north and west and are referred to as the South Equatorial Current. This current brings relatively cool, high salinity, nutrient-rich waters north from near Antarctica. Waters along the coast of Central America flow south and west and are referred to as the North Equatorial Current. This current brings relatively warm, nutrient-poor, and low salinity waters south.

Between the westerly flowing North and South Equatorial Currents, the surface Equatorial Countercurrent and the subsurface Cromwell Current both flow east, forming a transition zone. Depending on the season, this zone is commonly formed between the latitudes of 2° N and 1° S, which encompasses the Galapagos Islands. Strong vertical mixing occurs along the equator in the region of the Galapagos Islands because of the Equatorial Countercurrent and the upwelling of cool, nutrient-rich waters, which is caused by upward deflection of the subsurface Cromwell Current (Graham, 1975) and divergence in the surface wind field (Figure 3-4). This vertical mixing — together with the presence of shallow water and islands — allows for high biological productivity in the Galapagos region, (Wooster and Hedgpeth, 1966), and abundant marine life.

Coastal upwelling also occurs along the coast of South America, resulting in the biologically active coastal areas that support commercial fisheries (Figure 3-4). Coastal upwelling is common along the margins of continents, where wind conditions are such that adjacent surface waters are carried out to the open ocean via Ekman Transport (wind-driven transport of surface water away from a continental mass).

3.2.1.5 Biological Communities

Three distinct biological communities can be distinguished within the open equatorial Pacific Ocean: marine, hydrothermal vent, and coral reef. Hydrothermal vents are cracks along a rift or ridge in the deep ocean floor that spew water heated to high temperatures by the magma under the Earth's crust. These areas support species that are abnormally large in size given the depths of the vents. These communities are described below.

Figure 3-3
Currents Around the Major Oceanic Islands in the Tropical Pacific Ocean

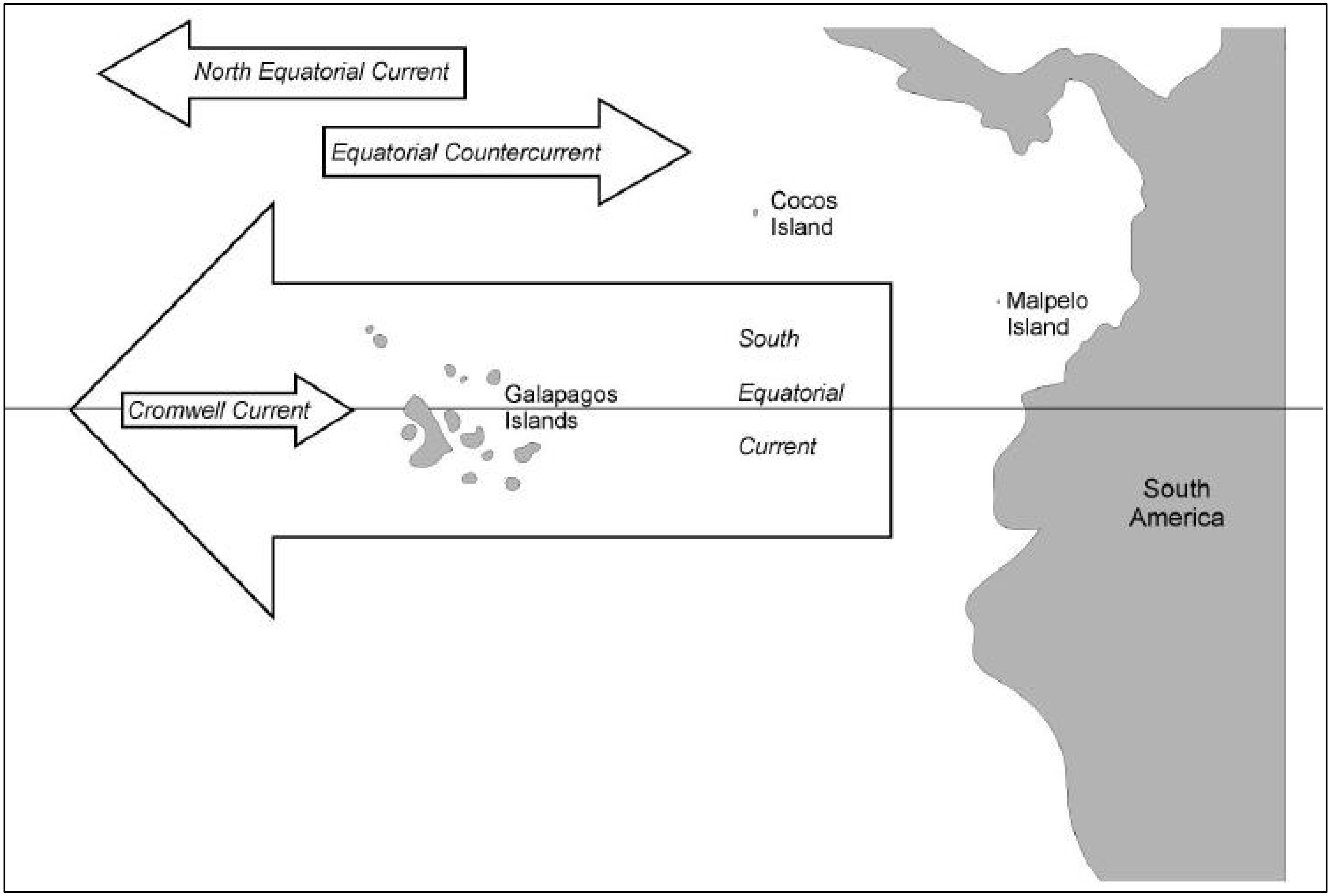
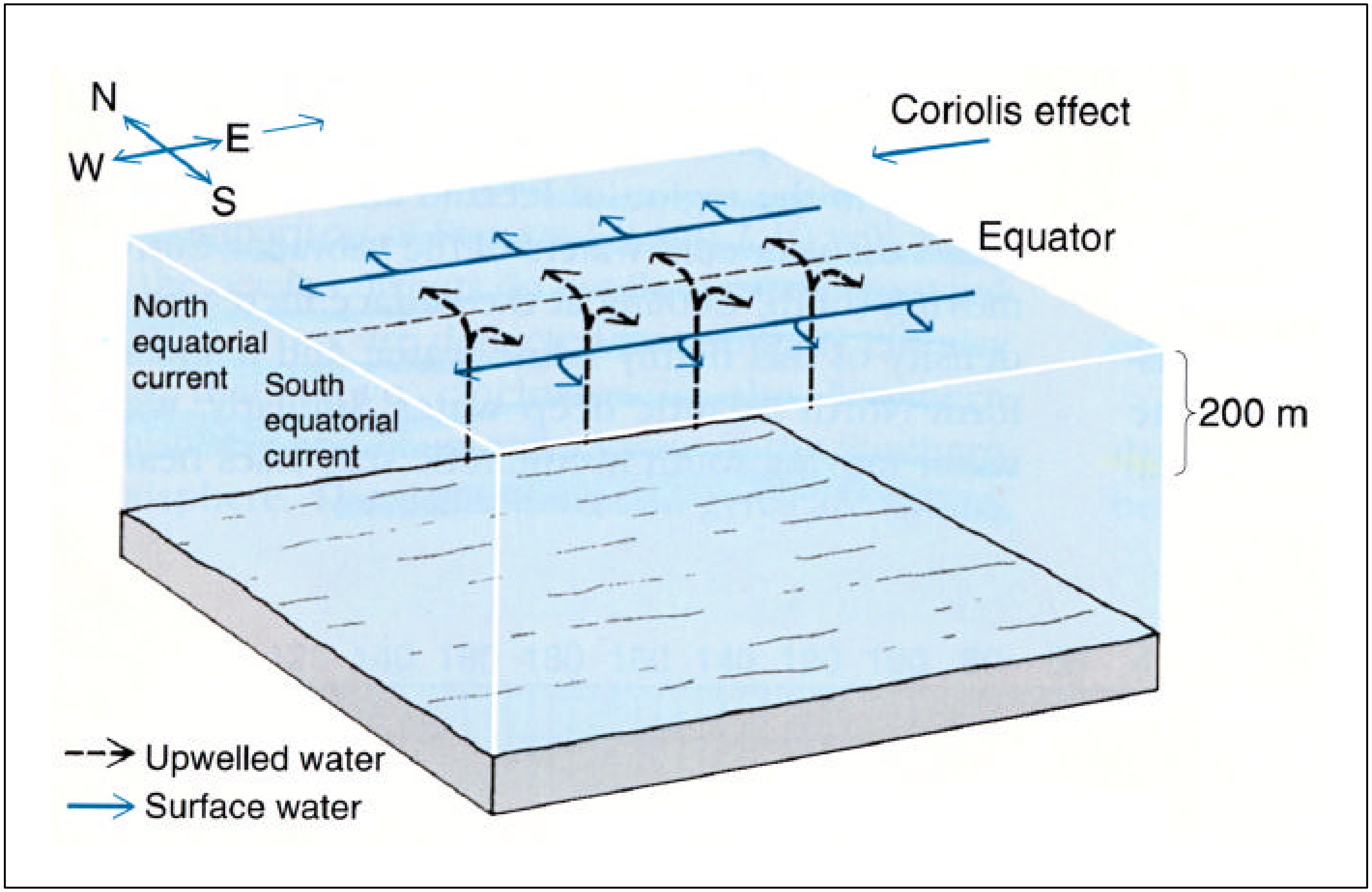


Figure 3-4
Equatorial Upwelling



Marine

Marine species diversity varies throughout the equatorial Pacific region because of the distinct differences in oceanographic processes (e.g., water temperature, and upwelling, as described in Section 3.2.1.3). The marine environment can be divided into the north, south, and transitional ecoregions, which are occupied by distinct groups of marine species.

In the north ecoregion, the North Equatorial Current transports tropical warm waters throughout the year (mean temperature of 20° C or 68° F). This current directly affects the northern Galapagos Islands, the only truly tropical region in the Galapagos, which exhibit high marine species diversity. Common species include the hammerhead shark (*Sphyrna lewini*), reef whitetip shark (*Triaendon obesus*), yellow fin tuna (*Thunnus albacares*), many species of pelagic (i.e., open ocean) fish, and shrimp.

The south ecoregion is dominated by the convergence of the Equatorial Countercurrent and the South Equatorial Current (see Figure 3-3), which — along with mixing winds — causes upwelling of cold (averaging around 15° C or 59° F), nutrient-rich waters. Marine diversity and productivity are high in such areas. Most of the marine species found in these waters originated in the cold waters of the Peruvian and Chilean Coasts. Characteristic species include a diverse variety of shorefish, an abundance of Peruvian anchoveta (*Engraulis ringens*) and pilchard (*Sardinops sagox sagap*), the Galapagos penguin (*Spheniscus mendiculus*), and the Galapagos shark (*Carcharhinus galapagensis*), which are attracted to the upwelled, nutrient-rich waters and corresponding food sources.

The transitional ecoregion is affected by cold water upwellings from the south and warm tropical waters from the north. This region is characterized by species from both the north and south regions, varying according to seasonal water temperature (Darwin Foundation, 2000). During the southern winter, this ecoregion experiences upwellings of cold water; during the southern summer, it experiences influxes of tropical waters.

The marine fauna in the Galapagos, Cocos, and Malpelo Island regions is similar with respect to species composition, with the exception of roughly 60 endemic or native species of shorefish that are restricted to individual islands within the Galapagos and Cocos Islands. No endemic species are known to occur at Malpelo Island (World Conservation Monitoring Center (WCMC), 2000). The marine fauna includes seven species of dolphins, seven species of sharks, four species of rays, and over 600 species of mollusks (WCMC, 2000). Roughly 298 fish species in 88 families have been recorded in the region. Shorefish exhibit high rates of endemism (approximately 23 percent) (Wolda, 1985).

Several species of migratory fish, reptiles, and mammals are found throughout these three marine ecoregions at various times of the year, including tuna, sea turtles, and whales.

Hydrothermal Vent

Diverse biological communities are associated with hydrothermal vents that occur along the Galapagos Rift spreading center. The organic content of the water in these areas is roughly 500 times greater than the normal bottom environment and four times greater than in typical surface waters (Thurman, 1988). Water temperatures in the immediate area of the vents range from 8° to 12° C (46° to 54° F), while the normal sea bottom temperature at this depth is usually 2° C (36° F).

These vent communities consist of unusually large organisms for these depths, with the most prominent members being pogonaphoran worms (*Rifta pachyptila*) with tubes over 1 m (3.3 ft) long, and giant clams (*Calyptogena magnifica*) over 25 centimeter (cm) (10 inch (in)) in length (Thurman, 1988).

The warm water that flows from the hydrothermal vents is rich in hydrogen sulfide. Chemosynthetic bacteria, which form the base of the food chain, use the energy released by their oxidation of hydrogen sulfide to fix carbon dioxide into organic matter. This process allows the bacteria to replace photosynthetic phytoplankton as the primary producers of organic matter in the otherwise desolate regions of the deep ocean (Thurman, 1988).

Coral Reef

Coral reefs in the eastern Pacific are poorly developed and have low species diversity when compared with those of the central and western Pacific (Glynn and Ault, 2000). This is primarily attributable to the lower water temperatures of the eastern Pacific, where ocean temperatures average 3° C (5° F) cooler than in the western Pacific (Durham, 1966), and to a relative lack of underwater platforms on which reefs can form. Corals in this area do not generally form true reef frameworks, but instead attach themselves to existing underwater structures (e.g., walls of underwater volcanoes). In a few locations, corals of the genus *Pocillopora* form reef-like frameworks (Durham, 1962).

Forty-four species of stony corals have been recorded in the Galapagos, 31 from Cocos, and seven from Malpelo (Glynn and Ault, 2000; Durham, 1962). In total, 52 species are known from these areas, with seven species common to all three island groups (Table 3-1).

The fringing reefs of Cocos Island are some of the more extensive and rich in the eastern equatorial Pacific (though still much less diverse than in the central or western Pacific). This diversity may be attributed to their location in the consistently warm waters of the north ecoregion (Guzman and Cortes, 1992; Durham, 1992). Twenty-eight species of corals are found in the Cocos reefs, the most abundant being *Porites californica* (Guzman and Cortes, 1992). Other common species include *Pocillopora robusta,* which occurs in small scattered patches at depths of one to eight meters, and *Tubastrea aurea,* which is common at various depths. The 1982-1983 El Niño phenomenon seriously affected the coral reefs of Cocos Island, causing about 90 percent of the coral to die. Although there are signs of recovery of the coral communities, it is evident that the intense feeding of sea urchins has weakened the coral foundation (de Alessi, 1997).

The Malpelo coral reef community contains seven species, none of which are endemic. Although coral growth is dense, no true coral reef is formed. The coral is interspersed among large barnacle clusters on the steeply sloping submerged walls of the volcano (Birkeland et al., 1985). At Malpelo, corals occur to depths of 30 m (100 ft); coral growth at this depth is attributed to the clear water around the island (Birkeland et al., 1985).

TABLE 3-1. STONY CORAL SPECIES OF THE GALAPAGOS, COCOS, AND MALPELO ISLANDS

Scientific Name	Location	Scientific Name	Location
Astrangia dentata	Cocos	*Pavona clivosa*	Galapagos
Astrangia eguatorialis	Galapagos	*Pavona explanulata*	Cocos
Astrangia gardnerensis	Galapagos	*Pavona gigantea*	Galapagos, Cocos
Astrangia hondaensis	Galapagos, Cocos	*Pavona maldirensis*	Galapagos, Cocos
Balanophyllia galapagensis	Galapagos	*Pavona ponderosa*	Cocos
Balanophyllia osburni	Galapagos	*Pavona varians*	Galapagos, Cocos, Malpelo
Carpophyllia diomedae	Galapagos	*Pavona varifae*	Cocos
Cindocora debilis	Galapagos, Cocos	*Pacillopora capitata*	Galapagos, Cocos
Cycloseris curvata	Galapagos, Cocos	*Pocillopora damicornis cespitosa*	Galapagos
Cycloseris elegans	Galapagos	*Pocillopora damicornis*	Galapagos, Cocos
Cycloseris mexicana	Galapagos, Cocos	*Pocillopora elegans*	Galapagos, Cocos, Malpelo
Desmophyllum galapagense	Galapagos	*Pocillopora eydouxi*	Galapagos, Cocos, Malpelo
Diaseris distorta	Galapagos, Cocos	*Pocillopora inflata*	Galapagos
Endopachys vaughani	Galapagos, Cocos	*Pocillopora meandrina*	Galapagos, Cocos
Flahellum daphnense	Galapagos	*Pocillopora verrucosa*	Galapagos, Cocos, Malpelo
Gardineroseris phamlota	Galapagos, Cocos, Malpelo	*Porites excavata*	Cocos
Kionotrochus avis	Galapagos	*Porites lobata*	Galapagos, Cocos, Malpelo
Kionotro chus hoodensis	Galapagos	*Psammocora brighami*	Galapagos
Leploseris digitata	Cocos	*Psammocora profundacella*	Galapagos, Cocos
Leploseris popvrucea	Cocos	*Psammocora stellata*	Galapagos, Cocos
Leploseris scabra	Galapagos, Cocos	*Psammocora superficialis*	Galapagos, Cocos
Lophosmilla wellsi	Galapagos	*Ralanophyllia osburni*	Galapagos
Madraeis asperula	Galapagos	*Ralanophyllia scheeri*	Cocos
Madraeis sp.	Galapagos	*Sphenotrochus hancocki*	Galapagos
Mudrepora galapagensis	Galapagos	*Thecopsammia pourtalesi*	Galapagos
Pavona clavus	Galapagos, Cocos, Malpelo	*Tubastrea tenuilamellosa*	Galapagos, Cocos

3.2.1.6 Threatened and Endangered Species

International lists of threatened, endangered, and vulnerable species and special habitats were consulted in addition to lists maintained by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service. Lists are maintained by international conservation organizations, including the International Union for Conservation of Nature and Natural Resources (IUCN) and the WCMC. The most comprehensive of these lists is the IUCN Red List of Threatened Animals (IUCN, 2000).

Table 3-2 lists threatened, endangered, or vulnerable, species of reptiles, birds, and mammals that could occur within the affected environment, as well as their listing agency or organization and their current status.

TABLE 3-2. THREATENED AND ENDANGERED SPECIES THAT COULD OCCUR WITHIN THE AFFECTED ENVIRONMENT*

Scientific Name	Common Name	Listing Agency/ Organization	Current Listing Status	Occurrence Within Study Area
Reptiles				
Conolophus pallidus	Barrington land iguana	USFWS, IUCN	Vulnerable	Oceanic Islands
Geochelone elephantopus abingdoni	Pinta Galapagos giant tortoise	USFWS, IUCN, WCMC	Extinct in the Wild	Oceanic Islands
Geochelone elephantopus becki	Galapagos giant tortoise	USFWS, IUCN, WCMC	Vulnerable	Oceanic Islands
Geochelone elephantopus chathamensis	Galapagos giant tortoise	USFWS, IUCN, WCMC	Vulnerable	Oceanic Islands
Geochelone elephantopus darwini	Galapagos giant tortoise	USFWS, IUCN, WCMC	Endangered	Oceanic Islands
Geochelone elephantopus elephantopus	Galapagos giant tortoise	USFWS, WCMC	Endangered	Oceanic Islands
Geochelone elephantopus ephippium	Galapagos giant tortoise	USFWS, IUCN, WCMC	Extinct in the Wild	Oceanic Islands
Geochelone elephantopus guntheri	Galapagos giant tortoise	USFWS, IUCN, WCMC	Endangered	Oceanic Islands
Geochelone elephantopus hoodensis	Galapagos giant tortoise	USFWS, IUCN, WCMC	Critically endangered	Oceanic Islands
Geochelone elephantopus microphyes	Galapagos giant tortoise	USFWS, IUCN, WCMC	Vulnerable	Oceanic Islands
Geochelone elephantopus phantastica	Galapagos giant tortoise	USFWS, WCMC	Endangered/possibly extinct	Oceanic Islands
Geochelone elephantopus porteri	Galapagos giant tortoise	USFWS, IUCN, WCMC	Endangered	Oceanic Islands
Geochelone vicina	Iguana Cove Tortoise	IUCN	Endangered	Oceanic Islands
Geochelone elephantopus vandenburghi	Galapagos giant tortoise	USFWS, IUCN, WCMC	Vulnerable	Oceanic Islands
Lepidochelys olivacea	Olive Ridley sea turtle	USFWS	Endangered	Oceanic Islands, open ocean
Chelonia mydas	Green turtle	USFWS, IUCN	Endangered	Oceanic Islands, open ocean
Eretmochelys imbricata	Hawksbill sea turtle	USFWS, IUCN	Critically endangered	Oceanic Islands, open ocean
Amblyrhynchus cristatus	Galapagos marine iguana	IUCN, WCMC	Vulnerable	Oceanic Islands, open ocean
Dermochelys coriacea	Leatherback turtle	USFWS, IUCN	Critically endangered	Oceanic Islands, open ocean

Scientific Name	Common Name	Listing Agency/ Organization	Current Listing Status	Occurrence Within Study Area
Conolophus subcristatus	Galapagos land iguana	IUCN	Vulnerable	Oceanic Islands
Mammals				
Neso ryzomys fernandinae	Fernandina rice rat	IUCN	Vulnerable	Oceanic Islands
Physeter catodon	Sperm whale	USFWS	Endangered	Open ocean
Orcinus orca	Killer whale	IUCN	Lower risk	Open ocean
Globicephalia macrorhynchus	Pilot whale	USFWS, IUCN	Lower risk	Open ocean
Megaptera novaeangliae	Humpback whale	USFWS, IUCN	Vulnerable	Open ocean
Balaenoptera physalus	Finback whale	USFWS, IUCN	Endangered	Open ocean
Balaenoptera musculus	Blue whale	IUCN	Endangered	Open ocean
Balaenoptera borealis	Sei whale	USFWS, WCMC	Endangered	Open ocean
Balaenoptera acutorostrata	Minke whale	USFWS, IUCN	Lower Risk	Open ocean
Stenella coeruleoalba	Striped dolphin	WCMC	Lower risk	Open ocean
Zalophus californianus wollebaeki	Galapagos sea lion	IUCN	Vulnerable	Oceanic Islands, open ocean
Arctocephalus galapagoensis	Galapagos fur seal	IUCN	Vulnerable	Oceanic Islands, open ocean
Birds				
Spheniscus mendiculus	Galapagos penguin	USFWS	Endangered	Oceanic Islands
Oceanodroma castro	Band-rumped storm petrel	USFWS	Critical	Oceanic Islands
Pterodroma phaeopygia	Dark-rumped petrel	IUCN	Critically endangered	Oceanic Islands
Buteo galapagoensis	Galapagos hawk	USFWS, IUCN	Vulnerable	Oceanic Islands
Phalacrocorax harrisi	Flightless cormorant	IUCN	Endangered	Oceanic Islands
Nesomimus trifasciatus	Floreana mockingbird (Charles mockingbird)	IUCN	Endangered	Oceanic Islands
Laterallus spilonotus	Galapagos Rail	IUCN	Vulnerable	Oceanic Islands
Larus fuliginosus	Lava gull	IUCN	Vulnerable	Oceanic Islands
Camarhynchus pauper	Medium tree-finch	IUCN	Vulnerable	Oceanic Islands
Camarhynchus heliobates	Mangrove finch	IUCN	Critically endangered	Oceanic Islands

Scientific Name	Common Name	Listing Agency/ Organization	Current Listing Status	Occurrence Within Study Area
Coccyzus ferrugineus	Cocos Island cuckoo	IUCN	Vulnerable	Oceanic Islands
Nesotriccus ridgwayi	Cocos Island flycatcher	IUCN	Vulnerable	Oceanic Islands
Pinaroloxias inornata	Cocos Island finch	IUCN	Vulnerable	Oceanic Islands

* For an explanation of listing status categories, see Appendix F.

Note: This table includes current threatened and endangered species listing information from the IUCN database (http://www.redlist.org/programme.html). The species list and listing categories were adopted by IUCN Council effective January 2001. This list includes listed species of reptiles, birds, and mammals that occur on the Galapagos Islands, Cocos Island, and Malpelo Island, and in the surrounding oceanic environment. This list does not include mainland- or coastal- Ecuador species. The IUCN lists over 150 total species for the Galapagos Islands, Cocos Island, and Malpelo Island.

3.2.1.7 Commerce

The equatorial Pacific is used by both commercial shipping and fishing vessels and is overflown by aircraft. These commercial uses of the open ocean portion of the affected environment are discussed below.

Shipping

In terms of commercial shipping, Figure 3-5 shows a sea-lane chart that identifies the affected environment. The area is primarily used as a shipping route for vessels from or to the Panama Canal and ports along the Pacific coast of the United States, Hawaii, Tahiti, and South America, including Callao (Ecuador) and Iquique (Chile).

It is difficult to estimate potential shipping traffic on any given day. Shipping data from the Panama Canal are useful in assessing the relative magnitude of traffic in the overflight area. The Panama Canal is designed to handle 50 ships per day, the maximum number of daily transits was 65.[1] In 1998 the average number of daily transits was 35.7.[2] The U.S. Gulf/East Coast to Asia and Europe to the West Coast of the United States and Canada are the major trade routes using the Panama Canal. These shipping routes are downrange of launches using the extreme lower azimuths (i.e., 83^o to 84^o). Table 3-3 lists the Panama Canal shipping routes and tonnage that routinely pass through the affected environment. Approximately 26 percent of the total tonnage shipped through the Panama Canal uses routes downrange of the launch. Some other route categories — such as “round the world” (at 20,250 thousand tons) and “all other routes, not otherwise classified” (at 17,621 thousand tons), which total an additional 17 percent of the tonnage shipped through the Panama Canal — may also pass through the affected environment. Therefore, using tons shipped as a surrogate for vessel traffic — 26 to 43 percent of Panama Canal traffic, or 10 to 17 vessels per day (26 to 43 percent of 40 daily transits) — may be in transit through the affected environment in route to or from the Panama Canal.

TABLE 3-3. PANAMA CANAL SHIPPING TRAFFIC

Panama Canal Traffic by Route	Tons (‘000s)
East Coast U.S. – West Coast South America	21,711
East Coast U.S./Canada – Oceania	5,157
Europe – West Coast South America	16,518
Europe – Oceania	2,653
South America Intracoastal	6,709
West Indies – West Coast South America	3,053
TOTAL	55,801

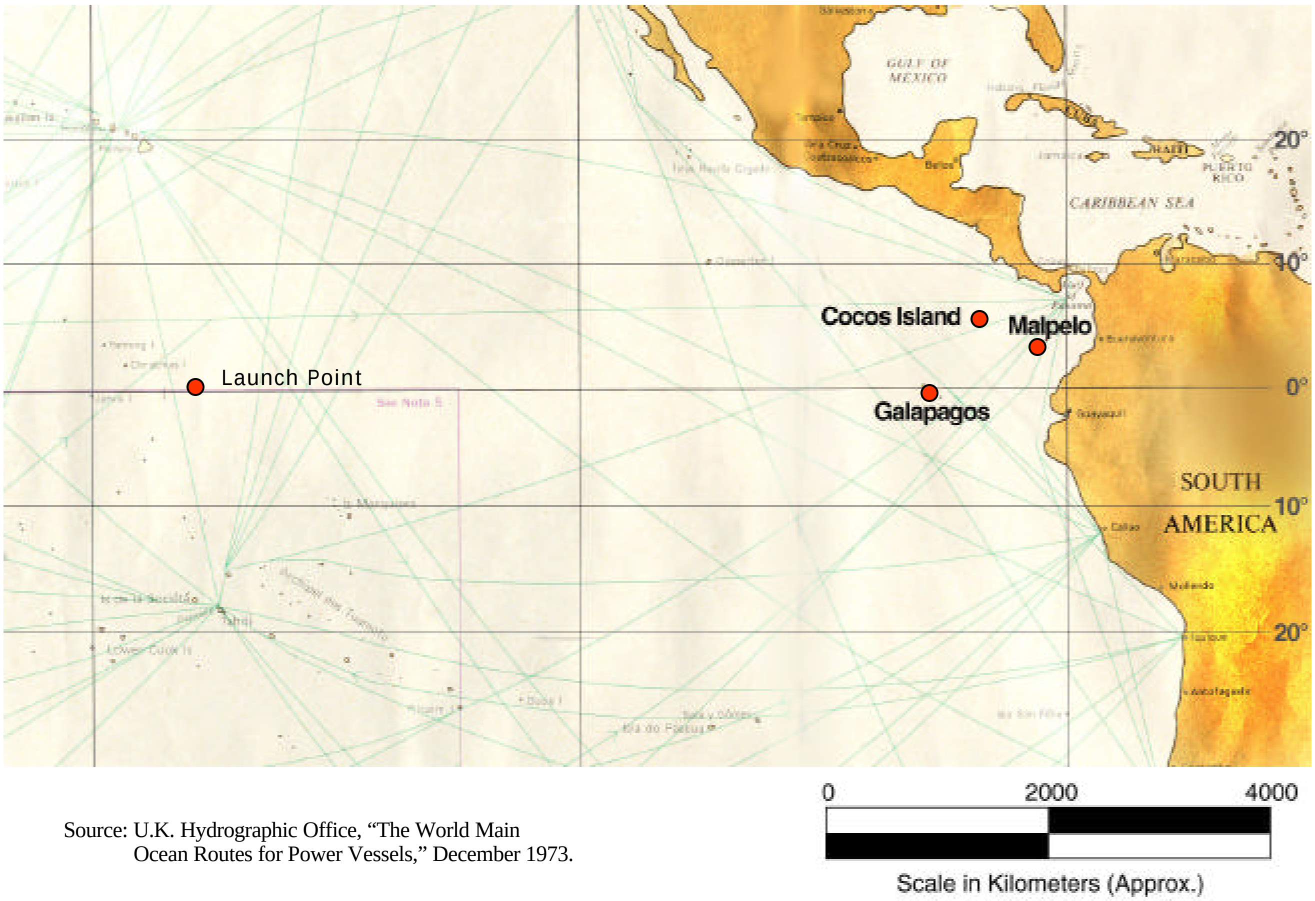
Source: http://www.orbi.net/pancanal/proposal/htraffic.htm

Commercial Fishing

Commercial fishing occurs within the affected environment, primarily by national fleets operating within their EEZs and territorial waters or by land-based foreign fleets operating under a license

[1] http://www.eia.doe.gov/emeu/cabs/panama.html
[2] http://www.eia.doe.gov/emeu/cabs/panama.html

Figure 3-5
Shipping Lanes of Equatorial Pacific Ocean



Source: U.K. Hydrographic Office, "The World Main Ocean Routes for Power Vessels," December 1973.

or fisheries agreement with a coastal nation. Within the affected environment, commercial fishing is most active south of the equator in the area influenced by the South EquatorialCurrent, which generates cold, nutrient-rich upwellings. These waters sustain the Peruvian anchoveta (*Engrautis ringens*) fishery, which is the largest single species fishery in the world (Food and Agriculture Organization (FAO), 1997). The area north of the equator, off the coast of northern Ecuador and Colombia, is affected by the North Equatorial Current, which has a relatively low productivity compared to the upwelling areas to the south. Commercial fisheries in this area include shrimp, small coastal pelagic species (i.e., herring), and large tropical migratory species such as yellow fin tuna (*Thunnus albacares*) and eastern Pacific bonito (*Sarda chiliensis*).

This area has experienced large fluctuations in fish production and major shifts in species composition over the past several decades. Much of this variability in abundance and composition is caused by changing environmental conditions, such as El Niño, that affect nutrient-bearing currents.

Based on overly-optimistic perceptions of fish abundance during productive years, fisheries expanded rapidly and catches exceeded sustainable levels, which contributed to major population declines (FAO, 1997). The collapse in fishery populations presents social and economic implications at the national, regional, and international levels. The southeast Pacific fishing industry is a major contributor to world fish production (accounting for almost 22 percent of the 1994 world marine fish production) (FAO, 1997). Most of the commercial fishery species in the region are considered to be fully to overly exploited (FAO, 1997).

Commercial fisheries are concentrated along the relatively narrow (maximum width 120 km or 75 mi) (FAO, 1997) continental shelf along the Pacific coast of South America. Areas suitable for bottom trawling are found off the coasts of Ecuador and northern Peru. As fishery stocks have become depleted closer to the South American coast, commercial fishing pressures have increased around the Oceanic Islands. In the 1980s, the lobster population was over exploited to the extent that the entire fishery was closed for two years, during which time there was a significant increase in the sea cucumber (*Sticopus fuscus*) harvest.

Some purse seining for tuna and long-lining for tuna, billfish, and shark occurs in and around the Galapagos. Ecuador's Congress passed the Special Law of Galapagos in 1998, and approved the Galapagos Marine Reserve Management Plan in 1999, both of which prohibit commercial fishing within 65 km (40 mi) of the coast of the Galapagos Islands. However, the constitutionality of the law is being challenged, and commercial fishing has not significantly decreased (Charles Darwin Research Station (CDRS), 2000).

Cocos Island is located in the less productive north ecoregion and is not subject to the same fishing pressures as the Galapagos Islands. Nevertheless, the Costa Rican Government has included the marine ecosystems up to a distance of 15 km (9 mi) around the island as part of a national park. The entire area was declared a zone of "absolute protection," where extraction of marine resources is banned (UNESCO, 2000). Although some commercial fishing traffic enters the 15-km (9-mi) zone, park rangers patrol the area.

Commercial fishing around Malpelo Island is limited. It has no specified zones for protection of marine ecosystems.

Commercial Air Traffic

The FAA National Ocean Service maps of commercial airline flight paths over the Pacific Ocean (Figure 3-6) indicate that four major air routes, from Los Angeles and San Francisco and one route from Hawaii, cross the affected environment. These major air routes intersect potential SLLP flight paths close to the launch site (all west of approximately 135^{o} W longitude). East of 135^{o} W longitude, which includes the majority of the airspace within the affected environment, is categorized as uncontrolled. This area includes potential SLLP flight paths over the open ocean and Oceanic Islands.

3.2.2 Oceanic Islands

The Oceanic Islands occurring within the overflight zone of the proposed project include the Galapagos Islands, Cocos Island, and Malpelo Island. This section provides an overview of the geology, atmospheric processes, biological communities, and social and economic conditions of these Oceanic Islands. The proposed project does not affect other aspects of the environment, such as noise and visual resources because the launch vehicle would not be audible or visible at the islands.

The Galapagos Islands (Figure 3-7) consist of 120 islands, rocks, and islets in the eastern Pacific Ocean, with a total land area of about 8,000 km^2 (3,100 mi^2). The Galapagos are a province of the Republic of Ecuador and are located 1,000 km (625 mi) west of the mainland. Cocos Island is located approximately 500 km (312 mi) west of the Pacific coast of Costa Rica. It is approximately 2 km (1.2 mi) long and 1 km (0.6 mi) wide (Figure 3-8). Cocos Island is governed by Costa Rica and is protected as a national park. Malpelo Island lies approximately 450 km (281 mi) west of Colombia in the equatorial Pacific Ocean. It is approximately 2.2 km (1.4 mi) long and 0.8 km (0.5 mi) wide. Malpelo Island is governed by Colombia (Figure 3-9).

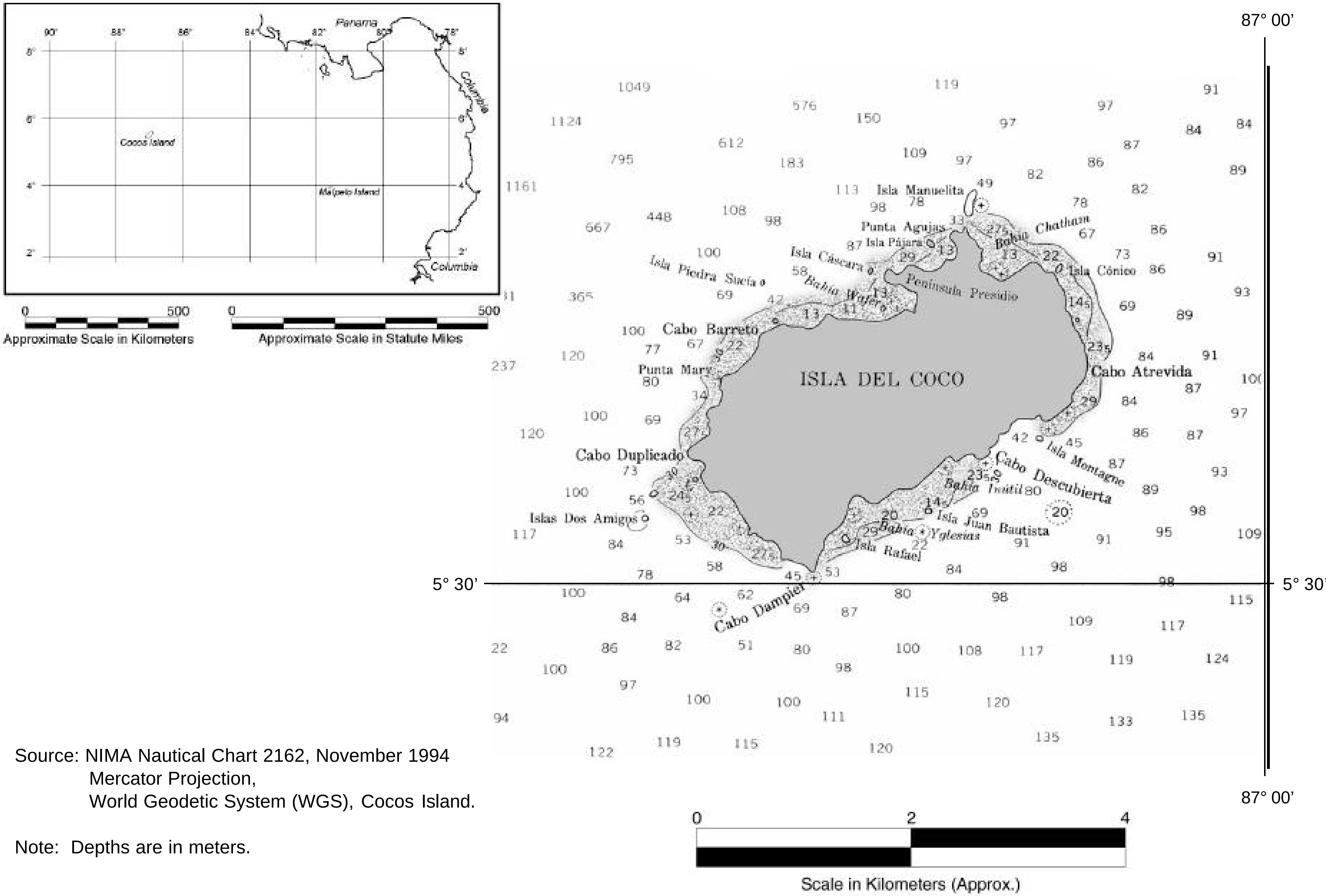
3.2.2.1 Geology

As with most islands in the equatorial Pacific, the three Oceanic Island groups are volcanic in origin. These islands, many of which are the summits of volcanoes, are the product of mantle plumes (molten rock) that have risen from the Earth's interior (Steadman, 1988). These volcanoes formed under the sea and then broke through the ocean floor, growing in size and eventually emerging from the surface of the water to become islands. The Galapagos Islands rise from the Galapagos Platform, located at the intersection of the Cocos and Carnegie submarine ridges (Wooster and Hedgpeth, 1966). Cocos Ridge extends northeastward toward Costa Rica, with a depth of less than 2,200 m (6,600 ft); and Carnegie Ridge extends eastward to Ecuador and Peru, with a depth of less than 2,600 m (7,800 ft; see Figure 3-3). Cocos Island is the only portion of the Cocos Ridge to appear above sea level. Malpelo Island, located between the Cocos and Carnegie Ridges, rises from the Malpelo Ridge (Meschede, 1998).

Figure 3-6

Figure 3-7

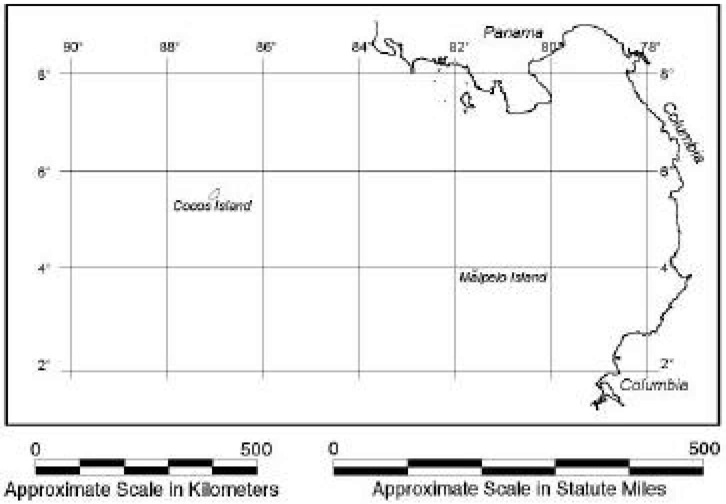
Figure 3-8
Cocos Island and Surrounding Waters

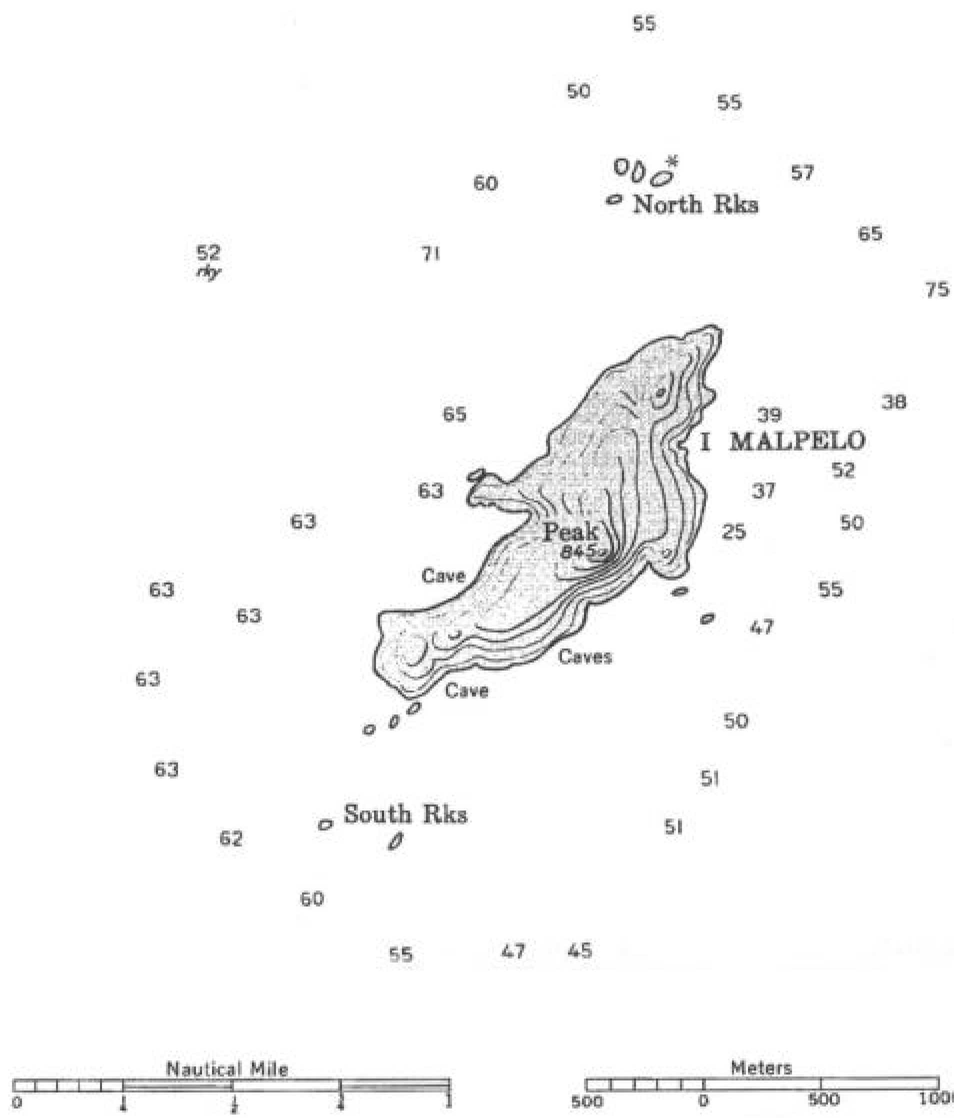


Source: NIMA Nautical Chart 2162, November 1994
Mercator Projection,
World Geodetic System (WGS), Cocos Island.

Note: Depths are in meters.

Figure 3-9
Malpelo Island and Surrounding Waters





Source: NIMA Nautical Chart 2162, November 1994

Peak, Lat. 3 59' 07" N., Long. 81 35' 40" W.

Note: Depths are in fathoms.

Galapagos Islands

Typical landscape features of the Galapagos Islands include crater lakes, fumaroles, lava tubes, sulfur fields, and a variety of lava and other volcanic materials such as pumice, ash, and tuff. As a result of their volcanic origin, the Galapagos Islands are composed almost exclusively of basalt. In geological terms, the Galapagos Islands are young, with the oldest islands being roughly three to four million years old (Williams, 1966). The larger islands typically consist of one or more sloping shield volcanoes, culminating in collapsed craters or calderas.

Minor volcanic eruptions and earthquakes are common in the Galapagos Islands. During the last 200 years, over 50 eruptions have been recorded from eight of the Galapagos volcanoes (Goff et al., 1999). The volcanoes are classified as shield volcanoes; they typically measure from 15 to 30 km (9.4 to 18.7 mi) across the base, with slopes gradually becoming steep upward to the rims of deep summit calderas with terraced walls (Wallace, 1966). The most active volcanoes are Fernandina and Isabela, the highest and westernmost islands in the Galapagos (Williams, 1966). The most recent eruptions occurred on Fernandina in 1995 and on Isabela in 1998. The least active volcanoes, and possibly the oldest, are Santa Maria, Espanola, and San Cristobal, the southeasternmost islands in the Galapagos.

Cocos Island

Cocos Island is approximately 2 km (1.2 mi) long and 1 km (0.6 mi) wide. It is located at the center of the volcanic Cocos Ridge, which runs from the Galapagos Islands to the Middle American Trench, southeast of Costa Rica. The island consists of basaltic rock and tuffacious breaches affected by trachytic intrusions. The jagged coast is lined with underwater caves and cliffs as high as 183 m (600 ft). The underwater profile consists of stepwise shelves with almost no intertidal zone and a shallow submerged fringing reef, which culminates in sand and rubble at the edge of a trench that is several hundred meters deep.

Malpelo Island

Malpelo Island is volcanic in origin. The present island is the remnant of a larger geologic structure. Malpelo is approximately 2.2 km (1.4 mi) long and 0.8 km (0.5 mi) wide and reaches a maximum height of 845 m (2,790 ft) above sea level. Wave action has eroded the island and formed steep cliffs (typically ranging from 60 to 230 m [200 to 760 ft] above sea level) and sea caves along its shoreline (Stead, 1975). Several types of igneous rocks are present on Malpelo Island, including dacite, trachyte, tuff, basalt, and andesite. Up to an elevation of 210 to 240 m (690 to 790 ft), the island is mostly trachyte, with lesser amounts of dacite and tuff. The higher elevations are covered by an andesite cap. Soil is scarce on the island and is completely absent at elevations below 90 m (300 ft) due to steep slopes and severe wave action (Stead, 1975).

3.2.2.2 Atmospheric Processes and Conditions

Atmospheric conditions and processes are the same as described in Section 3.4 of the February 11, 1999 EA and are incorporated by reference. (See Appendix A.)

3.2.2.3 Biological Communities

The three Oceanic Island groups lie at the convergence of several major ocean current systems of the equatorial Pacific (see Section 3.2.1.3). This location explains the variety of marine life and a climate that is classified as subtropical even though the islands are located near the equator. Table 3-4 provides information on the 22 primary islands within the three island groups. This section describes the terrestrial biological communities of the Galapagos, Cocos, and Malpelo islands.

Galapagos

Ecuador designated 97 percent of the land area of the Galapagos as a national park in 1959. In 1986, the Galapagos Marine Resources Reserve was established to protect the waters around the archipelago. The UNESCO recognized the Galapagos Islands as a Man and Biosphere Reserve and as a World Heritage Site. Ecuador manages the islands through the Galapagos National Park Service. The Charles Darwin Research Station (CDRS), which is operated by the Charles Darwin Foundation (CDF), carries out scientific research and assists the park service in managing the islands.

Table 3-4 lists terrestrial biological communities for 20 of the 120 Galapagos Islands. These 20 islands contain significant or unique biological communities. The remaining 100 islands are rocky projections that primarily support only nearshore algal communities or are only transiently used by fauna.

Approximately 625 species and subspecies of plants are native to the Galapagos Islands, of which 36 percent (225 species) are endemic. An additional 250 nonnative plant species have been introduced by human inhabitants. Vegetation can be divided into six zones, which are limited by elevation, moisture, and level of soil development (Schofield, 1984):

1) The Littoral Zone consists of Mangrove swamps of *Rhizophora mangle*, *Avicennia germinans*, and *Sesuvium sp.*
2) The Dry Zone is the most abundant habitat in the Galapagos Islands. It is located immediately inland from the coastal zone. Principal species characteristic of this zone are the cacti *Brachycereus sp.*, *Jasminocerus thouarsii*, *Opuntia sp*., and *Croton scouleri.* These species represent the only type of vegetation present on small islands of low elevation.
3) The Transition Zone consists of mixed shrub and forested habitat. A characteristic species is the palo santo tree (*Bursera sp.*).
4) The Scalesia Zone — similar to wet tropical forest — is dominated by *Scalesia sp.* and *Pisonia floribunda*.

TABLE 3-4. CHARACTERISTICS OF OCEANIC ISLANDS

Island	Location	Primary Habitats and Significant Natural Features	Characteristic Species	Major Human Activities
Galapagos Islands				
Pinta	0.55°N 90.75°W	Summit is 850 m (2,800 ft) above sea level and has no caldera. Island is characterized by young lavas and cinder cones. Introduction of goats to the island caused much ecological damage, and vegetation is sparse.	Once had a large tortoise population that was decimated by fishermen. One Pinta tortoise remains and is the last known individual of this species.	Uninhabited
Isabela	0.60°S 91.15°W	Largest island in the Galapagos, accounting for half of the total land mass. Has five active volcanoes and Darwin's Salt Lake Crater.	Flightless cormorant, Galapagos penguin, blue-footed booby, masked booby, marine turtles, sea lions.	Inhabited Cattle herding (300 head)
Santa Fè	0.95°S 90.12°W	Oldest island in the Galapagos. Has a sheltered bay, steep cliffs, and an area of Opuntia cactus. Eroded volcanic cones called "cerros" mark the youngest parts of the island. Other features include spatter cones, pit craters, and small calderas.	Sea lion, Galapagos white-tipped shark, marine turtle, Galapagos hawk, frigatebird, pelican, swallow-tailed gull, mockingbird.	Uninhabited Visited by tourists
Bartolomè	0.25°S 90.50°W	Evokes a lunar landscape of cones and craters. Stark and dry, only the occasional prickly pear, lava cactus, or Scalesia bush. Lies opposite of Sullivan Bay. Pinnacle Rock is one of the best known landmarks of this island.	No information available.	Uninhabited
Marchena	0.33°N 90.50°W	With Pinta and Genovesa, Marchena forms the northern trio of islands just above the equator. A large shield volcano of which only the upper 343 m (1,130 ft) is above sea level.	Southern Martin, small tree finch, large tree finch, Marchena lava lizard	Uninhabited Marchena is closed to tourists; however, divers frequent the surrounding waters.

Island	Location	Primary Habitats and Significant Natural Features	Characteristic Species	Major Human Activities
Santa Maria	1.25°S 90.45°W	Beach, enclosed lagoon, forest. The terrain rises and falls in proliferation of volcanic cones. The western part of the island consists of bare lava flows and a black sand beach. In the northeastern portion of the island is Punta Cormorant's lagoon. An imploded volcano, Devil's Crown, lies just off the coast of the main island.	Sea lion, marine turtle, ghost and sally lightfoot crabs. Flamingo and several other bird species feed in the lagoons and ponds.	Inhabited The first inhabited island of the Galapagos (since 1807). Cattle farming (300 head).
San Cristobal	0.80°S 89.45°W	Home to the capital and administrative center of the Galapagos Islands, Puerto Baquerizo Moreno. Provides habitat for five endemic species (three reptiles, two birds)	Tuberculated leaf-toed gecko, San Cristóbal leaf-toed gecko, San Cristóbal lava lizard, San Cristóbal snake, red bat, paint-billed crake, Galápagos barn owl, San Cristóbal vermilion flycatcher, San Cristóbal mockingbird, vegetarian finch.	Inhabited Airport located on the island. Puerto Baquerizo Moreno is the oldest settlement in the Galapagos.
Culpepper	1.65°N 92.00°W	Encircling reef extends 400 m (0.25 mi).	Largest breeding colony of sooty tern in the Galapagos, large cactus finch.	Uninhabited Inaccessible due to absence of landing areas. Protected as a natural area by the Ecuador Government.
Daphne Major/Minor	0.40°S 90.35°W	Sparsely vegetated by herbaceous and shrub vegetation. Two small craters host thousands of nesting blue-footed boobies. Consists of 3 islets.	Swallow-tailed gull, brown noddy, blue-footed booby, masked booby, red-billed tropicbird	Uninhabited
Pinzon	0.70°S 90.70°W	18-km^2 (7 mi^2), 458-m (1,510 ft) volcano peak, entirely cliff bound. Provides habitat for one endemic reptile species.	Pinzón lava lizard, Slevin's snake.	Uninhabited

Island	Location	Primary Habitats and Significant Natural Features	Characteristic Species	Major Human Activities
Espanola	1.45°S 89.67°W	Punta Suarez has 30-m (100 ft) high cliffs that provide nesting habitat for many seabird species. Gardner Bay provides feeding habitat for many bird species and beach habitat for sea lions and marine iguanas. Encircling reefs extend 400 m (0.25 mi).	Masked booby, blue-footed booby, Galapagos dove, hooded mockingbird, cactus finch, warbler finch, waved albatross, sea lion, marine iguana, lava lizard.	Uninhabited One of the most visited islands due the variety of animals. Landing point is Punta Suarez.
Santa Cruz	0.60°S 90.35°W	The central island in the Galapagos and home to the main port, Puerto Ayora, and the Charles Darwin Research Station. Highly diverse flora and fauna. Mangrove forest, arid forest dominated by polo santo trees and prickly pears, Miconia shrubland. Tortoise reserve at Parte Alta twin craters. The island's peak is at 900 m (2,970 ft) above sea level. Cow pastures and small plantations in the island interior.	Galapagos tortoise, red bat, lava lizard, mockingbird, ground finch, vermilion flycatcher.	Inhabited Puerto Ayora, the largest town in the Galapagos, is the main tourist destination in the islands.
San Salvador	0.25°S 90.75°W	The shoreline of Perto Egas characterized by cliffs of hard volcanic ash. Primary habitat is polo santo forest. Feral goats have consumed most of the vegetation, turning much of the land into an open savannah. A salt crater, Sugarloaf volcano (390 m or 1,290 ft), is located in James Bay. Sullivan Bay is known for its conical volcano.	Fur seal, flamingo, masked booby, pelican, feral goat.	Uninhabited Commercial attempts to extract minerals from the salt lake crater failed. Today, only a few roads and abandoned buildings remain.
Rabida	0.42°S 90.72°W	A small island 2 km (1.2 mi) in width and 400 m (0.25 mi) at its highest point. Known for its unusual red-colored beaches. Vegetation consists of Opuntia cactus, polo santo trees, and shrubland.	Sea lion outhaul area, flamingo, penguin. Nine of 13 species of finch occur here.	Uninhabited Visited by tourists
Wenman	1.38°N 91.82°W	Rocky, barren island.	Seabird nesting area.	Uninhabited Inaccessible due to the absence of landing sites.

Island	Location	Primary Habitats and Significant Natural Features	Characteristic Species	Major Human Activities
Fernandina	0.35°S 91.55°W	The westernmost island of the Galapagos and one of the most volcanically active. One of the newest of the Galapagos volcanoes, evident by the lack of erosion and bareness of vegetation. Young mangrove forest is the primary habitat. Rocky shores, black sand beaches, and frequent volcanic upheavals. The main volcano is 1,500 m (4,950 ft) high with a diameter of 6.5 km (4 mi), depth of 800 m (2,640 ft), and a 910 m (3,000 ft) deep caldera.	Heron, yellow warbler, pelican, frigatebird, mangrove finch, petrel, shearwater, Galapagos penguin, fur seal, flightless cormorant, vegetarian finch, sharp-beaked ground finch, Galápagos barn owl, black rail, large Fernandina rice rat, Slevin's snake, Galápagos lava lizard, Galapagos leaf-toed gecko. Feral goats and rats.	Inhabited Visited by tourists; landing point is called Punta Espinosa.
Seymour	0.40°S 90.25°W	No information available.	Known for its large nesting colony of great and magnificent frigatebirds. The blue footed booby, land iguana, swallow-tailed gull, pelican, and red-billed tropicbird also nest here.	Uninhabited
Plaza Sur	0.60°S 90.10°W	Smallest of the 13 large islands. Dry sandy land.	Sea lion, land iguana, marine iguana.	Uninhabited Visited by tourists
Baltra	0.45°S 90.25°W	Approximately 100 m (330 ft) above sea level.	Land iguana, marine iguana, marine turtle.	Inhabited Airport located on the island
Genovesa	0.35°N 89.97°W	A small island (10 km^2, or 3.9 mi^2) in the shape of a horseshoe. One of the most pristine islands of the Galapagos group. Polo santo trees on the cliffs are a major breeding site for water and land birds. The island's interior, Darwin Bay, an imploded volcano, is the dominant natural feature. Encircling reefs are present.	Important breeding site for marine, land, and water birds, including red-footed booby, masked booby, frigatebird, wandering tattler, turnstone, whimbrel, lava gull, yellow-crowned heron, lava heron, black-crowned night heron, finch, Galapagos mockingbird, and Galapagos dove. One reptile species, a subspecies of marine iguana.	Uninhabited Visited by tourists (particularly birders).

Island	Location	Primary Habitats and Significant Natural Features	Characteristic Species	Major Human Activities
Cocos Island				
	5.55°N 87.00°W	Coastline is irregular, with cliffs rising a lmost vertically to 200 m (660 ft). Inland terrain is mountainous with numerous rivers and streams. Primary habitats include a herbaceous zone and a montane cloud forest zone. Two bays (Bahi`a Wafer and Bahi`a Chatham). Largest watercourses are the Genio and Pittier Rivers. Highest peak (Cerro Iglesias) is 634 m (2,090 ft).	High numbers of endemic plant and animal species. 87 bird species have been recorded, including 3 endemic (Cocos Island cuckoo, Cocos Island flycathcer, and Cocos Island finch); 2 endemic reptiles (Anolis lizard and gecko). Feral pigs, goats, and cats are the only terrestrial mammals.	The Government of Costa Rica took official possession of Cocos in 1869. After two unsuccessful attempts to colonize the island, it has remained free of permanent human intervention except for 10-15 resident park rangers.
Malpelo Island				
	4.00°N 81.58°W	400 m (1,320 ft) long and 545 m (1,800 ft) wide. Highest peak is 350 m (1,150 ft) above sea level. Flora limited to lichens and fern.	Anolis and anguid lizards, 10 species of birds. Masked booby and swallow-tailed gull nesting site. Large migrations of hammerhead and whale sharks occur just offshore.	Island has fewer than 10 Colombian Coast Guard employees; otherwise, it is uninhabited. Colombia has nearly completed the processes for designating Malpelo as a nature reserve.

Source: United Nations Environmental Program, UN System-Wide Earthwatch Web Site; WCMC, 2000; Gorman and Chorba, 1985; Wolda, 1985; Slud, 1967.

5) The Miconia Zone commonly referred to as the shrub zone — is found primarily on Santa Cruz. It is characterized by dense, monotypic stands of cacaotillo shrubs (*Miconia robinsoniana*).
6) The Fern-Sedge Zone covers the summit areas of the larger islands, where moisture is retained in temporary pools and Sphagnum moss. Endemic tree ferns (*Cyathea weatherbyana*) and various grass and sedge species occupy collapsed lava tubes and other small potholes.

Because the Galapagos Islands have always been separated from the mainland, the plants that occur there arrived by long distance dispersal. Most of the plant species were derived from South America, with some from Mexico and Central America (Schofield, 1984). Historically, birds are believed to be the major source of plant dispersal in the Galapagos, with wind and ocean currents having a minor influence. In modern times, humans have introduced approximately 250 plant species to the Galapagos Islands (Schofield, 1984). Several of these introduced plants have dramatically changed the landscape of the islands. Large areas of all of the inhabited islands have been invaded by guayaba (*Psidium guajava)* and elephant grass (*Pennisetum sp*.), which, in many areas, have completely replaced native vegetation. Orange and lemon trees are widespread in the Scalesia zones of San Cristobal and Santa Maria, often excluding the native *Scalesia* and *Pisonia* species.

Table 3-5 provides information on the common reptiles and birds that occur on the Galapagos Islands. Except for two species of marine tortoises, all of the reptile species are endemic. These include the Galapagos giant tortoise (*Geochelone)*, with 11 subspecies on different islands; two species of land iguanas; one species of marine iguana; three species of snakes; and several species of *Tropidurus* lizards and *Phyllodactilus* geckos. The native avifauna includes 57 residents, of which 26 (46 percent) are endemic and 31 are regular migrants. Endemic bird species include 13 species of finch (collectively known as Darwin's finches), eight species of seabirds, and five species of land birds. Six indigenous mammal species are found on the islands: the Galapagos fur seal, Galapagos sea lion, two species of rice rat, and two species of bat. There are roughly 1,000 insect species, 50 spiders, and 60 land snail species documented in the region, some of which are endemic to individual islands (WCMC, 2000). Sally lightfoot crab (*Graspus graspus)* is a characteristic shoreline species on all islands within the Galapagos.

Cocos Island

Although Cocos Island has a less diverse flora than that of the Galapagos Islands, it has a similar percentage of endemic species [35 percent (70 species) of vascular plants compared with 36 percent on the Galapagos]. The flora of Cocos Island consists of 235 vascular and 137 nonvascular plants (Fournier, 1966). Two plant zones are found on the island (Gomez, 1975):

- A coastal, mostly herbaceous, Littoral Zone, which rises between 0 to 50 m (0 to 165 ft), with two habitat types: the *Annona glabra* swamp and the firm terrain with various species of flowering plants.
- A montane cloud forest zone (Mountainous Zone), which grows to 100 m (330 ft). The predominant tree species include the endemic species *Huriki sacglottis holdridgei*, *Ocotea insularis*, and *Cecropia pittieri*. Undergrowth in the forest is dense with *Hypolitrum amplum* and several species of ferns (Dauphin, 2000).

TABLE 3-5 COMMON BIRD AND REPTILE SPECIES OF THE GALAPAGOS, COCOS, AND MALPELO ISLANDS

Latin Name	English Name	Distribution	Endemic
Reptiles			
Geochelone elephantopus	Galápagos tortoise (12 subspecies)	All major islands except Genovesa, Marchena, Culpepper, Wenman; extinct on Santa Maria, Santa Fé, Rábida, and perhaps Fernandina.	X
Chelonia mydas agassizii	Green turtle	Widespread throughout the Galapagos (endemic subspecies).	X
Phyllodactylus tuberculosus	Tuberculated leaf-toed gecko	San Cristóbal	X
Phyllodactylus gilberti	Wenman leaf-toed gecko	Wenman	X
Phyllodactylus leei	San Cristóbal leaf-toed gecko	San Cristóbal	X
Phyllodactylus barringtonensis	Santa Fé leaf-toed gecko	Santa Fé	X
Phyllodactylus galapagoensis	Galapagos leaf-toed gecko	Santa Cruz, Daphne Major, San Salvador, Pinzón, Crowley, Tortuga, Isabela, Fernandina	X
Phyllodactylus sp.	Rábida leaf-toed gecko	Rábida	X
Phyllodactylus bauri	Baur's leaf-toed gecko	Española, Gardner near Española, Santa Maria, Gardner near Santa Maria, Enderby, Champion	X
Sphaerodactylus pacificus	Gecko	Cocos	X
Phyllodactylus sp.	Gecko	Malpelo	
Norops townsendi	Anolis lizard	Cocos	X
Anolis agassizi	Anolis lizard	Malpelo	
Celestus hancocki	Anguid lizard	Malpelo	
Tropidurus pacificus	Pinta lava lizard	Pinta	X
Tropidurus duncanensis	Pinzón lava lizard	Pinzón	X
Tropidurus habelii	Marchena lava lizard	Marchena	X
Tropidurus bivittatus	San Cristóbal lava lizard	San Cristóbal	X
Tropidurus delanonis	Española lava lizard	Española, Gardner near Espanola	X
Tropidurus grayii	Floreana lava lizard	Santa Maria, Gardner near Santa Maria, Caldwell, Enderby, Champion	X
Tropidurus albemarlensis	Galápagos lava lizard	Santa Fé, Santa Cruz, San Salvador, Rábida, Isabela, Fernandina	X

Latin Name	English Name	Distribution	Endemic
Conolophus subcristatus	Land iguana	Santa Cruz	X
Conolophus pallidus	Santa Fé land iguana	Santa Fé	X
Amblyrhynchus cristatus	Marine iguana	Throughout the Galapagos on all major islands	X
Alsophis biserialis eibli	San Cristóbal snake	San Cristóbal	X
Alsophis biserialis hoodensis	Española snake	Española, Gardner near Española	X
Alsophis dorsalis dorsalis	Galápagos snake	Santa Fé, Santa Cruz, Baltra, San Salvador, Rábida	X
Alsophis Dorsalis helleri	Isabela snake	Isabela, Tortuga	X
Alsophis dorsalis occidentalis	Fernandina snake	Fernandina	X
Alsophis slevini slevini	Slevin's snake	Pinzón, Isabela, Fernandina	X
Alsophis slevini steindachneri	Steindachner's snake	Santa Cruz, Baltra, San Salvador, Rábida	X
Pelamis platurus	Yellow-bellied sea snake	Widespread throughout Galapagos	X
Seabirds			
Spheniscus mendiculus	Galapagos penguin	Throughout the Galapagos	X
Diomedea leptorhyncha	Waved albatross	Nearly endemic, but also breeds in small numbers on Isla La Plata, off Ecuador.	
Pterodroma phaeopygia phaeopygia	Dark-rumped petrel	Throughout the Galapagos	Endemic subspecies
Puffinus lherminieri subalaris	Audubon's shearwater	Throughout the Galapagos	Endemic subspecies
Oceanites gracilis galapagoensis	White-vented storm petrel	Throughout the Galapagos	Endemic subspecies
Oceanodroma tethys tethys	Wedge-rumped storm petrel	Throughout the Galapagos	Endemic subspecies
Oceanodroma castro	Band-rumped storm Petrel	Throughout the Galapagos	Endemic subspecies
Phaethon aethereus mesonauta	Red-billed tropicbird	Throughout the Galapagos	Endemic subspecies
Pelecanus Occidentalis urinator	Brown pelican	Throughout the Galapagos	Endemic subspecies

Latin Name	English Name	Distribution	Endemic
Sula nebouxii excisa	Blue-footed booby	Throughout the Galapagos	Endemic subspecies
Sula dactylatra granti	Masked booby	Throughout the Galapagos	Endemic subspecies
Sula sula websteri	Red-footed booby	Throughout the Galapagos	Endemic subspecies
Phalacrocorax harrisi	Flightless cormorant	Throughout the Galapagos	X
Fregata minor ridgwayi	Great frigatebird	Throughout the Galapagos, Cocos	X
Fregata magnificens	Magnificent frigatebird	Throughout the Galapagos	X
Haematopus palliatus galapagensis	American oystercatcher	Throughout the Galapagos	Endemic subspecies
Larus fuliginosus	Lava gull	Throughout the Galapagos	X
Larus Furcatus	Swallow-tailed gull	Nearly endemic to Galapagos, but also breeds on Malpelo	X
Sterna fuscata crissalis	Sooty tern	Throughout the Galapagos, large breeding colony on Culpepper	X
Anous stolidus galapagensis	Brown noddy	Throughout the Galapagos	Endemic subspecies
Anous stolidus ridgwayi	Noddy	Malpelo	
Anous minutus diamesus	Black noddy	Malpelo	
Actitis macularia	Spotted sandpiper	Malpelo	
Heteroscelus incanus	Wandering tattler	Malpelo	
Waterbirds			
Ardea herodias cognata	Great blue heron	Throughout the Galapagos	Endemic subspecies
Ardea alba egretta	Great egret	Throughout the Galapagos	Endemic subspecies
Ardeola sundevalli	Lava heron	Throughout the Galapagos	X
Ardeola striata cf. Striata	Striated heron	Throughout the Galapagos	X
Nyctanassa violacea pauper	Yellow-crowned night heron	Throughout the Galapagos	Endemic subspecies
Laterallus jamaicensis spilonotus	Black rail	Santa Cruz, Baltra, San Salvador, Pinta, Isabella, Fernandina	Endemic subspecies
Neocrex erythrops	Paint-billed crake	San Cristóbal, Santa Maria, Santa Cruz, Isabella	Endemic subspecies

Latin Name	English Name	Distribution	Endemic
Gallinula chloropus (cachinnans or pauxilla)	Common gallinule	Throughout the Galapagos	Endemic subspecies
Himantopus himantopus mexicanus	Common stilt	Throughout the Galapagos	Endemic subspecies
Phoenicopterus ruber glyphorhynchus	Greater flamingo	Throughout the Galapagos	Endemic subspecies
Anas bahamensis galapagensis	White-cheeked pintail	Throughout the Galapagos	Endemic subspecies
Land Birds			
Buteo galapagoensis	Galápagos hawk	Throughout the Galapagos, except for Genovesa, Wenman, Culpepper	X
Falco peregrinus	Peregrine falcon	Throughout the Galapagos, Malpelo, Cocos	
Zenaida galapagoensis	Galápagos dove	Throughout the Galapagos	X
Coccyzus melacoryphus	Dark-billed cuckoo	Throughout the Galapagos	X
Tyto punctatissima	Galápagos barn owl	San Cristóbal, Santa Cruz, San Salvador, Isabela, Fernandina	X
Asio flammeus galapagoensis	Short-eared owl	Throughout the Galapagos	Endemic subspecies
Pyrocephalus nanus	Galápagos vermilion flycatcher	Throughout the Galapagos, except for San Cristóbal	X
Pyrocephalus dubius	San Cristóbal vermilion flycatcher	San Cristóbal	X
Myiarchus magnirostris	Large-billed flycatcher	Throughout the Galapagos	X
Progne concolor	Southern Martin	Throughout the Galapagos, except for Genovesa, Marchena, Pinta, Wenman, Culpepper, Malpelo	X
Mimus parvulus	Galápagos mockingbird	Throughout the Galapagos, except for San Cristóbal	X
Mimus melanotis	San Cristóbal mockingbird	San Cristóbal	X
Mimus macdonaldi	Española mockingbird	Española	X
Mimus trifasciatus	Floreana mockingbird	Champion, Gardner near Santa Maria	X
Dendrocia petechia aureola	Yellow warbler	Throughout the Galapagos	X
Geospiza nebulosa	Sharp-beaked ground finch	Santa Maria, Santa Cruz, San Salvador, Isabela, Fernandina, Pinta	X

Latin Name	English Name	Distribution	Endemic
Geospiza fuliginosa	Small ground finch	Throughout the Galapagos, except for Genovesa, Culpepper, Wenman	X
Geospiza fortis	Medium ground finch	Throughout the Galapagos, except for Genovesa, Wenman	X
Geospiza magnirostris	Large ground finch	Throughout the Galapagos, except for Española, Culpepper	X
Geospiza scandens	Small cactus finch	Throughout the Galapagos, except for Española, Fernandina, Genovesa, Culpepper, Wenman	X
Geospiza conirostris	Large cactus finch	Española, Genovesa, Culpepper, Wenman	X
Geospiza crassirostris	Vegetarian finch	San Cristóbal, Santa Maria, Santa Cruz, Isabela, Fernandina, Pinta	X
Geospiza parvula	Small tree finch	Throughout the Galapagos, except for Española, Genovesa, Marchena, Culpepper	X
Geospiza pauper	Medium tree finch	Santa Maria	X
Geospiza psittacula	Large tree finch	Throughout the Galapagos, except for Española, Genovesa, Marchena, Culpepper, Wenman	X
Geospiza pallida	Woodpecker finch	Throughout the Galapagos	X
Geospiza heliobates	Mangrove finch	Isabela, Fernandina	X
Geospiza olivacea	Warbler finch	Throughout the Galapagos	X
Coccyzus ferrugineus	Cocos Island cuckoo	Cocos	X
Nesotriccus ridgwayi	Cocos Island flycatcher	Cocos	X
Pinaroloxias inornata	Cocos Island finch	Cocos	X
Icterus pectoralis	Spot-breasted oriole	Cocos	
Hirundo rustica ethrogaster	Barn swallow	Malpelo	

Source: WCMC, 2000; Steadman and Zousmer, 1988; Gorman and Chorba, 1985; Wolda, 1985; Slud, 1967.

Table 3-5 provides information on the common birds and reptiles that occur on Cocos Island. The fauna on Cocos includes 87 bird species, three of which are endemic species listed as endangered: the Cocos Island cuckoo (*Coccyzus ferrugineus*), Cocos Island flycatcher (*Nesotriccus ridgwayi*), and Cocos Island finch (*Pinaroloxias inornata*; Slud, 1967). Several seabird breeding colonies exist on the surrounding emerged rocks, including the red-footed booby (*Sula sula*), brown booby (*S. leucogaster*), great frigatebird (*Fregata minor*), white tern (*Gingis alba*), and common noddy (*Anous stolidus*). Two species of endemic reptiles are found on the island: the *anolis* lizard (*Norops townsendii*) and a gecko (*Sphaerodactylus pacificus*).

The only terrestrial mammals on the island are introduced pigs, goats, and cats. Over 362 species of insects have been documented on Cocos, including 64 endemic species. The endemic spider (*Wendilgarda galapagensis)* expresses habitat selection and web building behavior that differs from other species of its genus in Central and South America (Eberhard, 1989).

Cocos Island was added to the UNESCO World Heritage List in 1997 and was subsequently designated a Wetland of International Importance (RAMSAR, 1998).

Malpelo Island

Because soil is scarce on Malpelo Island, there are few suitable substrates for plant life. Consequently, plant species are dominated by lichens (71 species) and bryrophytes (113 species), which grow on the island's volcanic surface. The only vascular plant known to occur on Malpelo is a species of fern (*Pityrogramma dealbata*).

Correspondingly, the resident terrestrial faunal diversity of Malpelo Island is low. Ten species of birds are present (three land birds and seven seabirds), two species of lizards (*Anolis agassizi* and *Celestus hancocki*), one species of gecko (*Phyllodactylus sp.*), one land crab (*Gecarcinus malpilensis*), and 37 species of invertebrates (Abele, 1985; Wolda, 1985). Table 3-5 provides information on the common reptiles and birds that occur on Malpelo Island. None of these species are endemic to Malpelo; they are found throughout the equatorial Pacific region. There are no terrestrial mammals on the island. The masked booby (*Sula dactylatra granti*) and swallow-tailed gull (*Creagrus furcatus*) have significant breeding colonies (more than 50 pairs) on the island and its surrounding rocks (Pitman et al, 1995).

3.2.2.4 Social and Economic Conditions

Galapagos Islands

The Galapagos had no aboriginal inhabitants and was discovered in 1535 by Tomas de Berlanga, the Bishop of Panama. During the 17th and 18th centuries, buccaneers used the islands as a staging post, stocking up on water and giant tortoises. During the 19th century, whalers and fur sealers further exploited the islands for ship stores. Ecuador annexed Galapagos in 1832, and small colonies were gradually established on several of the islands (Galapagos Conservation Trust, 2000). In 1959, the Government of Ecuador declared 97 percent of the Island Group a national park, with the remainder available for the resident population.

Until the 1970s, there were no more than 1,000 residents on the Galapagos. They were primarily involved in subsistence fishing activities. From 1974 to 1999, tourism contributed to an influx of immigrants from the mainland, which caused the Galapagos population to rise from approximately 3,500 to 16,184 (Ecuadorian National Census and Statistics Institute, 2000). Population on the islands increased at a rate of 7.8 percent from 1990 to 1995, with only 1.7 percent due to natural increases and 6.1 percent due to immigration from the mainland (UNESCO, 2000).

Over 80 percent of the population lives on the islands of Santa Cruz, San Cristobal, Isabela, and Santa Maria. The capital is Puerto Baquerizo Moreno on San Cristobal Island, though the largest town is Puerto Ayora on Santa Cruz Island. Largely because of tourism, these two islands have experienced the greatest population growth over the past 10 years. The Government of Ecuador, as part of the Special Law of Galapagos, limits permanent resident status to Ecuadorians who have been on the islands for five years or more. UNESCO projects the population of the Galapagos Islands to grow to 20,000 people by 2003, 40,000 people by 2015, and 80,000 people by 2027 (UNESCO, 2000).

Tourism, which has dramatically increased since the 1970s from nearly none to more than 70,000 visitors annually, is the primary source of revenue for the islands. Tourism activities include wildlife observation, scuba diving, and snorkeling. The upgrade of two airports on San Cristobal and Baltra in the 1980s allowed for the landing of larger capacity jet aircraft. Some of those living on the islands, however, still depend on subsistence fishing for food and income. These fishermen use lines and nets, and dive for lobster. The number of local subsistence fishermen in the Galapagos has increased from less than 200 in 1971 to roughly 800 in 1999 (UNESCO, 2000).

The Galapagos Islands, because of unique flora and fauna, support an active scientific research program. The CDRS is based on Santa Cruz Island and is jointly supported by the Government of Ecuador, IUCN, and UNESCO, with additional funding from a variety of European and U.S. conservation bodies and from private donors.

Cocos Island

The Government of Costa Rica took official possession of Cocos Island in 1869. After two unsuccessful attempts at colonization, the island has never sustained a permanent population. The island was declared a national park in 1978. Its only inhabitants are 10 to 15 park rangers who reside there for short periods of time (WCMC, 2000). Visitors (mainly divers) are allowed on the island for day hikes, but not for overnight stays. The nearby reefs are a popular diving destination, with an average of 1,100 visitors per year (UNESCO, 2000). Scientific research has been extensive, including studies of land birds, island flora, biogeographic affinities of insects, and the impacts caused by introduced pigs and tourism. There are no facilities for researchers other than the lodges for rangers.

Malpelo Island

Until recently, Malpelo Island, governed by Colombia, was uninhabited and seldom visited. In 1986, the Colombia Coast Guard established a station on Malpelo Island, which usually has a staff of fewer than 10 people (WCMC, 2000). No significant tourism industry exists on the island. Because of a lack of a diversified fauna and animal population, there are no known scientific research activities at Malpelo Island at this time. The endemic lizard population has been studied on various occasions since the 1970s. There are no facilities for researchers on the island.

3.2.3 South America

Although continental South America is outside the predicted impact zone of stage and fairing debris, Section 3.2.3 provides a brief overview of the affected environment between 7.4° N and 7.4° S of the equator (see Figure 3-1). The upper-stage and payload would cross this area of continental South America at an altitude of over 180 km (112 mi).

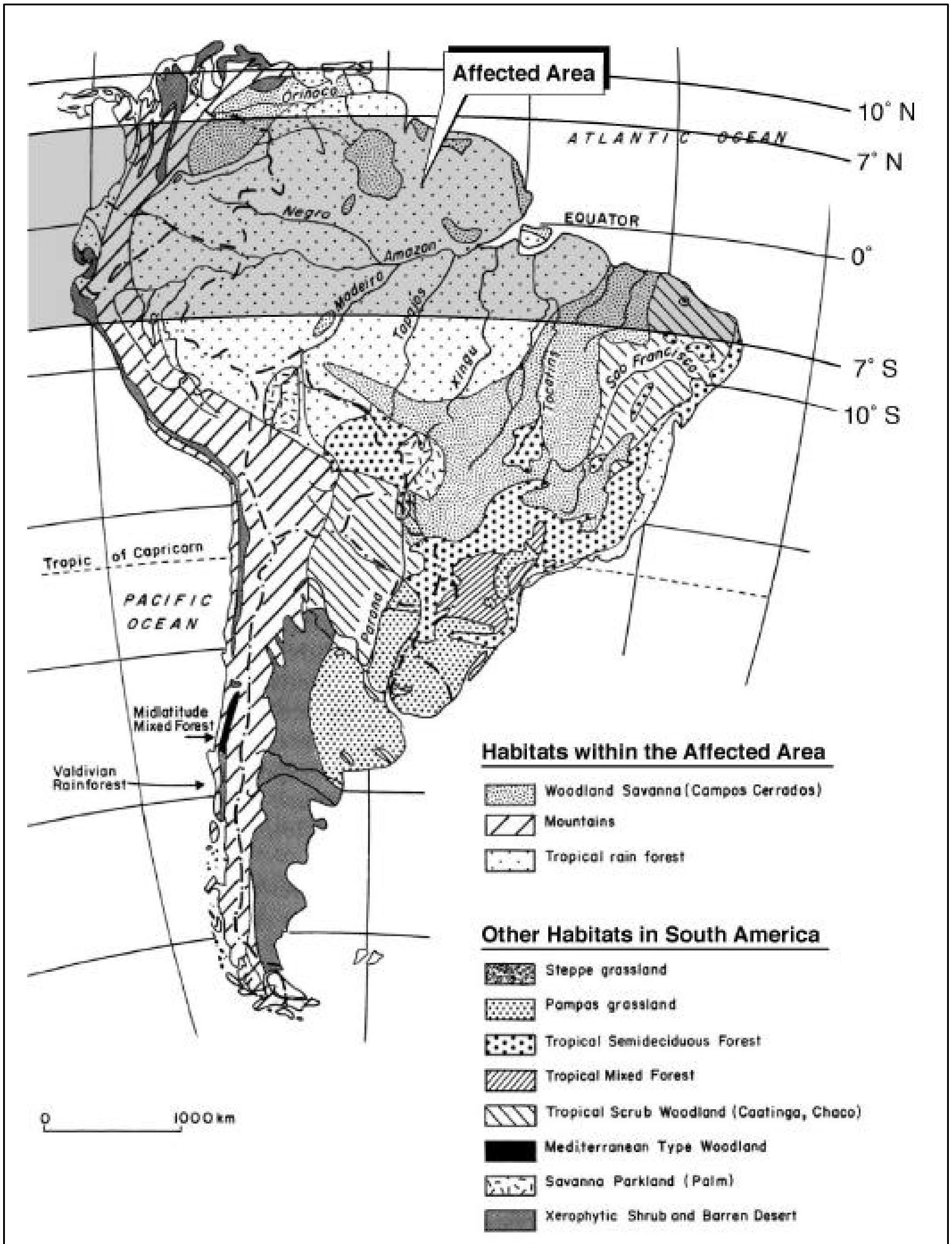
The portion of South America and Central America within the affected environment includes all of Ecuador, Surinam, and French Guiana, and portions of Colombia, Venezuela, Peru, Brazil, Guyana, and Panama. There are 29 national parks or national reserves—three of which are on the UNESCO World Heritage Site List—located within this affected environment (Hammond, 1996; UNESCO, 2001). The portion of South America within the affected environment generally consists of three geographical areas traversing from west to east: the Pacific coastal lowlands, the Andean mountain range (including high elevation valleys and plateaus), and the eastern lowlands (including much of the Amazon River Basin; see Figure 3-10). Each of these areas is described below in terms of geology, biological communities, and demographics. The proposed project would not affect other aspects of the environment—such as atmospheric conditions, aesthetics, noise, socioeconomics, and cultural resources—because the payload would cross South America at an altitude of over 180 km (112 mi), which is above the mesosphere (see discussion in Section 3.4 of the February 11, 1999 EA).

3.2.3.1. Pacific Coast and Coastal Lowlands

The Pacific coastline is generally steep and rocky, but is interspersed with sandy beaches, barrier islands, and brackish lagoons. The flat coastal lowlands variably extend 16 to 160 km (10 to 100 mi) inland from the Pacific coast to the foothills of the Andes. The northern part of these coastal lowlands in Colombia and northern Ecuador is covered by tropical rainforest, which transitions to relatively arid conditions in southern Ecuador and northern Peru (Clapperton, 1993).

These lowland forests support a diversity of animal life, including anteaters, sloths, several monkey species, tapirs, peccaries, deer, and large rodents such as agoutis, pacas, and capybaras. Large carnivores, such as pumas and jaguars, are increasingly rare.

Figure 3-10
Major Natural Vegetation Zones of South America



Source: Clapperton, 1993.

The coastal lowlands — with their hot and humid climate, dense rainforests, infertile soils, and rocky coastline — are sparsely populated. One major exception is Guayaquil, Ecuador's largest city, which has a population of over 2 million and is located at one of the few natural harbors along South America's Pacific coast.

3.2.3.2. Andean Mountain Range

Tectonic forces formed the Andean mountain range when the spreading Atlantic seafloor thrust the South American plate up and over the eastern margin of the Nazca and Caribbean plates. As is common along the margins of tectonic plates, the Andean mountain range includes numerous volcanoes and is commonly subject to earthquakes. Pre-Cretaceous metamorphic and plutonic rocks characterize the underlying geology. The Andes are among the world's youngest mountain ranges and among the highest, reaching elevations above 6,000 m (19,800 ft) (Clapperton, 1993).

Plant life in the Andean Mountains is strongly influenced by elevation and precipitation. Many species are specific to relatively narrow altitudinal bands. Alpine rain tundra forms at the highest elevations below the snow line and is dominated by lichens and bryophytes. A subalpine rain zone has three main vegetation types: tussock grassland, cushion plants and other low-growing species, and bamboo. Montane rainforest is found at lower elevations [(below approximately 3,500 m (11,500 ft)] and in the valleys. Subtropical rainforest occurs below elevations of 2,200 m (7,200 ft), with very high species diversity (Clapperton, 1993). Figs, laurels, palms, and wild avocado are common canopy trees.

The faunal species distribution in this region is related to altitudinal vegetation zones. At the highest elevations, mountain tapir, puma, guinea pig, and Andean fox are common. At lower elevations, spectacled bear, jaguar, ocelot, and various deer species are present. Over 1,500 species of birds are found in the Andean region, including toucans, hummingbirds, and songbirds (Ridgely, R.S., 1994; Altman A., 2000).

Despite their high elevations, the fertile valleys of the Andean region are the primary centers of population and economy. In this area of South America, alluvial soils found along principal river valleys and soils of volcanic origin are exceptionally productive and support agriculture, especially coffee farming. Major cities include Bogota (pop. 6.0 million), Medellin (pop. 2.0 million), and Cali (pop. 2.0 million) in Colombia and Quito in Ecuador (pop. 1.4 million).

3.2.3.3. Eastern Lowlands

The eastern lowlands form the majority of the Amazon River Basin and extend eastward from the foothills of the Andes (generally below 1,000 m or 3,300 ft) nearly to the Atlantic Ocean. This region consists of gently undulating topography in the west transitioning to relatively flat topography in the east along the Amazon River. A large freshwater sea occupied these lowlands during the Pliocene Epoch (5.3 to 1.6 million years ago). An outlet to the Atlantic was subsequently established, and the Amazon and its tributaries formed in the former seafloor (Bigarella and Ferreira, 1985).

The Amazon River drains approximately 6 million km^2 (2.3 million mi^2) and is the largest river in the world in terms of volume. Most of the rivers that drain the eastern Andes are tributaries to the Amazon, including the Putumayo, Japura, Maranon, and Negro rivers. The basin experiences high rainfall for most of the year, with precipitation averaging approximately 3,000 millimeters (mm) (119 in) annually (Salate, 1985). Around June, the Amazon overflows its banks, floods over 64,000 km^2 (25,000 mi^2) of land referred to as the varzea, and deposits nutrients that enrich the alluvial soils. The remaining portion of the Amazon basin is referred to as terra firme or upland areas.

These eastern lowlands are dominated by tropical rainforest, or selva (Pires and Prance, 1985). The Amazon rainforest is incredibly complex and has among the highest biodiversity anywhere in the world. Approximately 25 percent of the world's primary forests are located within the confines of the Amazon basin. The rainforest is composed of several layers. In the canopy, enormous trees such as the rubber tree, silk-cotton, Brazil nut, sapucaia, and sucupira reach heights in excess of 67 m (220 ft). Two or three layers of smaller shade-tolerant trees are found below the canopy, including palms, myrtles, laurels, figs, mahogany, and rosewoods. Throughout the canopy and subcanopy are many epiphytes, such as orchids and bromeliads, ferns, and mosses. A network of woody vines called lianas links the entire forest. Over 2,500 species of trees alone are found in the Amazon.

The rainforest also provides habitat for a diverse array of animal species (Junk and de Silva, 1997). Many of the mammals are arboreal and live in trees, such as monkeys and sloths. Other mammals include the tapir, the white-lipped peccary, several species of deer, and many rodents. Carnivores include jaguar, ocelot, pumas, coati, and weasels. The Amazon basin is rich in bird life, with parrots, macaws, hoatzins, woodpeckers, parakeets, many species of waterbirds, and ground-dwelling birds such as tinamous and quail (Petermann, 1997). Insects represent the largest percentage of Amazonian organisms, with more than 8,000 species classified (including mosquitoes, black flies, beetles, cicadas, spiders, and butterflies) and likely many more yet unidentified.

The Amazon and its tributaries support over 2,500 species of fish, including pirarucu, various catfish, and piranha (Junk, et al., 1997). Crocodiles, manatees, freshwater dolphins, and several aquatic mammals such as the capybara, are all found in and along the Amazon's rivers.

Most of this region is sparsely populated. The few inhabitants are generally confined to small settlements at the foot of the Andes, along the banks of the main rivers, and along the Atlantic coast. New roads extending from the Andes encourages colonization. Major cities in the rainforest include Iquitos (pop. 280,000) in Peru and Manaus (pop. 1.0 million) in Brazil. Major port cities along the Atlantic coast include Belem (pop. 1.5 million) and Macapa (pop. 89,000) in Brazil, Cayenne (pop. 38,000) in French Guiana, Paramaribo (pop. 216,000) in Surinam, and Georgetown (pop. 250,000) in Guyana.

3.3 LEGAL FRAMEWORK

The legal framework is the same as described in Section 3.6 of the February 11, 1999 EA and is incorporated by reference. (See Appendix A.)

4.0 ENVIRONMENTAL CONSEQUENCES

This section of the EA evaluates the environmental effects of the license applicant's proposed action and each of the alternatives identified for further analysis in Section 2.6. Section 4.1 evaluates the environmental effects of the license applicant's proposed action. Section 4.2 evaluates the environmental effects of the alternative with avoidance of the Oceanic Islands. Section 4.3 evaluates the environmental effects of the alternative with avoidance of the Galapagos Islands. Section 4.4 evaluates the environmental effects of the No Action alternative.

4.1 ENVIRONMENTAL EFFECTS OF LICENSE APPLICANT'S PROPOSED ACTION

This section of the EA evaluates the environmental effects of the license applicant's proposed action. To frame this discussion, SLLP operations are broadly grouped into five phases - Home Port, pre-launch, launch, successful flight (separated into Stages I, II, and Upper Stage), and post-launch. Possible failed mission scenarios at the LP, and during flight of Stages I and II and the Upper Stage are discussed. SLLP payloads (i.e., commercial satellites), which would be loaded with propellants and sealed at Home Port, are not addressed because they become operational only when in orbit at an altitude over 35,000 km (21,700 mi). Environmental effects of payloads are discussed only with regard to possible failed mission scenarios.

As detailed in Section 2.2 of this EA, the license applicant's proposed action is for the FAA to issue an LOL for up to eight launches per year for a period of five years up to a maximum of 40 launches. These launches would be conducted over a range of azimuths (82.6^{o} to 97.4^{o}, inclusive) using a specified launch vehicle at a specified launch location for specific payload types. In general, the reader is referred to the February 11, 1999 EA, Section 4.3 for a discussion of the primary environmental impacts of the proposed project during operations at Home Port, pre-launch, launch and post-launch operations, and failure scenarios.

Impacts attributable to the range of azimuths, which affect both successful flight and the possible failure scenarios, are discussed below in Sections 4.1.1 and 4.1.2. Possible cumulative impacts attributable to the license applicant's proposed action are discussed in Section 4.1.3. The discussion of cumulative effects also considers, as a worst-case situation, the possible failure of successive launches that affect the same geographic area. Section 4.1.4 addresses other environmental concerns, such as socioeconomic considerations.

4.1.1 Environmental Effects of Successful Flight

4.1.1.1 Home Port

Under the license applicant's proposed action the environmental effects associated with the preparation of the ACS, LP, and ILV for transit to the launch site are equivalent to those described in Section 4.5.3 and Appendix A of the February 11, 1999 EA. Section 4.1.3 of this EA addresses cumulative environmental impacts associated with the license applicant's proposed action at Home Port.

The use of UDMH during operations at SLLP Home Port will require SLLP to modify Federal, state, and local regulatory documentation prior to the use of UDMH. The following documents needed to be modified:

1. Hazardous Material Inventory, (EPCRA) Long Beach Department of Health (CUPA)
2. Business Emergency Plan, Long Beach Fire Department

3. Operations Manual for the Transfer of Hazardous Material in Bulk, (USCG)
4. Integrated Contingency Plan, (EPA), (OSHA), California OSHA,
5. California Offshore Emergency Service (COES), (USCG)

The following document which will be published in 2002, will reflect emission changes occurring in 2001:

1. Annual Emissions Inventory (Year 2001), (SCAQMD)

The following document will not require changes because regulated thresholds would not be exceeded:

1. Risk Management Plan, Long Beach Department of Health, (CUPA)

Scrubbers are the components of scrubber filters specifically designed and constructed to capture and neutralize UDMH vapors. These filters have been installed at the Home Port facility.

4.1.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

Propellant loading would occur after arrival at the launch location. This would result, under normal operations, in an incidental loss of kerosene and LOX vapors, which would dissipate immediately in the atmosphere over the Pacific Ocean. Up to 125,000 liters (33,000 gallons) of freshwater from a tank on the LP would be sprayed into the LP's flame bucket to absorb energy during the initial fuel burn. The heat of the ILV exhaust would evaporate approximately 80 percent of this water, while the remainder would be dispersed by the force of the launch and settle on the ocean surface as spray or mist. This small volume of heated freshwater would cool to ambient ocean temperatures within minutes with no significant adverse effects on any marine life.

The ILV would be launched from the LP and Stage I and II flight would occur over open ocean areas. In this respect, the environmental effects associated with Stage I and II components and their operation during a successful launch along any azimuth in the license applicant's proposed action would be the same as those evaluated in Sections 4.3.2 and 4.5.5 of the February 11, 1999 EA. These include:

- Spent stages, fairing, and sleeve adapter (i.e., connection between Stage II and the Upper Stage) deposition in the ocean,
- Combustion emissions released to the atmosphere,
- Residual propellants released from spent stages to the atmosphere and ocean, and.
- Possibility of spent stages, fairing or sleeve adapter falling on a marine organism, ship, fishing vessel, or aircraft.

Section 3.2 of the February 11, 1999 EA categorized the affected environment in terms of geology, atmospheric processes, oceanography, biological communities (including marine, hydrothermal vent, coral reef, and threatened and endangered species), and commercial operations (including shipping, fishing, and air traffic). The following discussion categorizes the expected environmental effects in the same manner.

Geology

As shown in Figure 4-1, Stage I and fairing impact zones overlap slightly, and jointly form a rectangle of approximately 480 km (north to south) by 600 km (east to west) (300 by 375 mi). These impact zones are located between the Clipperton Fracture Zone and the Galapagos Fracture Zone in the eastern-equatorial

Pacific Ocean in water 2,000 to 4,000 m (1.2 to 2.5 mi) deep. The Stage II impact zone is approximately 1,270 km (790 mi) by 1,320 km (820 miles) located just west of the Galapagos Rift. The water depth in these areas is approximately 3,900 m (2.4 mi). Given the geologic setting, the deposition of spent stages and the fairing in these areas would be inconsequential relative to expanse of the open ocean environment and natural geologic processes in the region.

Oceanography and Atmospheric Processes

The open ocean environment within the proposed range of azimuths is largely uniform in terms of oceanic and atmospheric processes, with biological characteristics (e.g., plankton biomass) primarily varying with nutrient and mineral levels (Barber, et al., 1996). The spent stages and fairing pieces from any launch within the proposed range of azimuths would fall into undifferentiated deep, open waters of the tropical equatorial Pacific Ocean, far away from any Oceanic Islands or continental land mass (see Tables 4-1 and 4-2 and Figure 4-1).[a]

TABLE 4-1. IMPACT ZONES FOR SPENT STAGES AND FAIRING

Flight Element		Open Ocean Impact Zone		
Component	**Mass in kg (lbs)**	**Latitude**	**Longitude**	**Area in km^2 (mi^2)**
Stage I	36,500 (80,300)	2ºS to 2ºN	147.7ºW to 145.5ºW	107,000 (41,800)
Fairing halves*	2,400 (both) (5,280)	2.2ºS to 2.2ºN	146.6ºW to 142.2ºW	240,000 (93,800)
Stage II and sleeve adapter	11,515 (25,333)	6ºS to 6ºN	116.6ºW to 105.1ºW	1,680,000 (660,000)

* Data shown are for the potential 5-m (16.5 ft) fairing

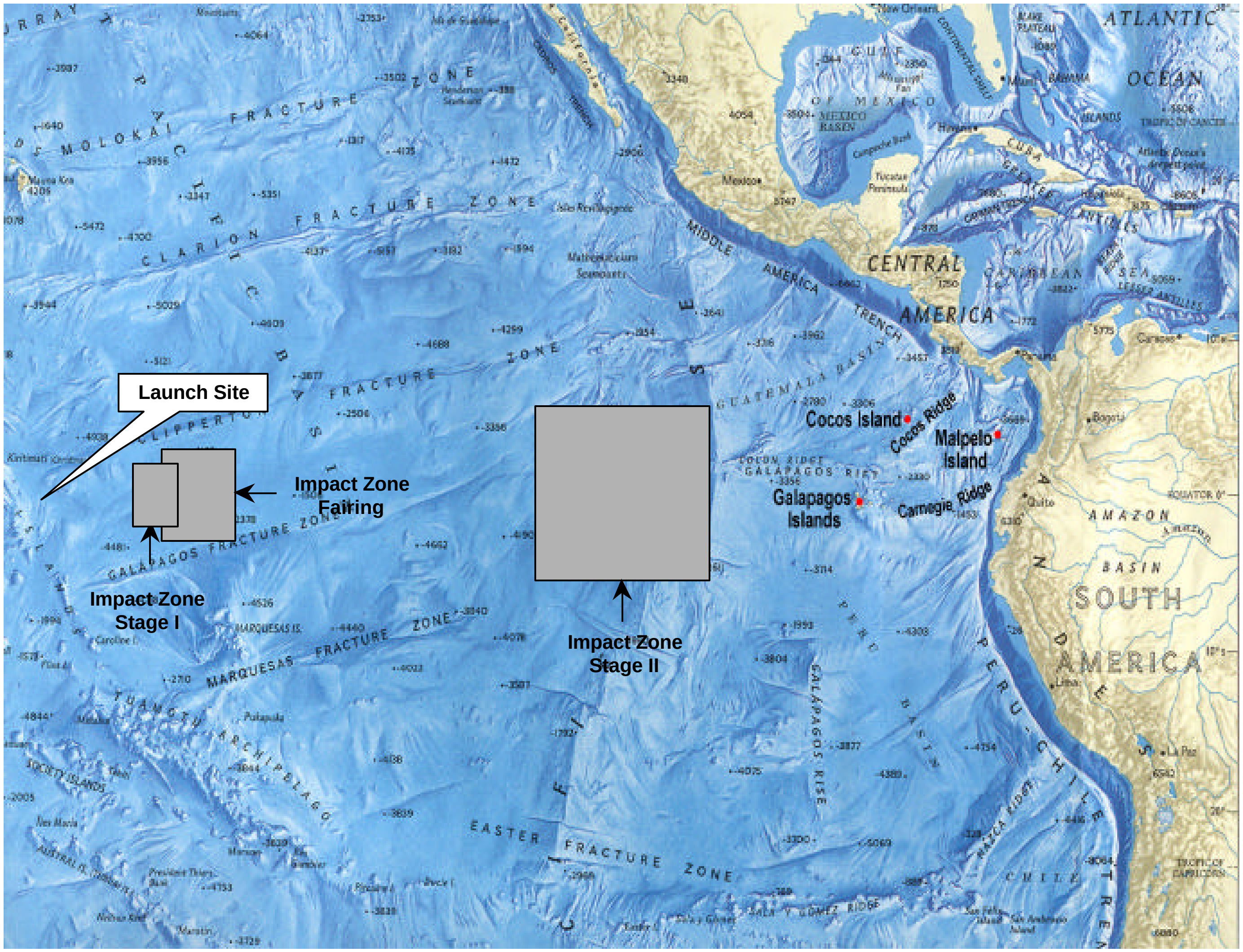
[a] The fairing and Stage I and Stage II impact zones are outside the area of the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (1986) ("Convention"). Article 2 of the Convention defines the "Convention Area" as:

(i) the 200 nautical mile zones established in accordance with international law off:
American Samoa; Australia (East coast and Islands to eastward including Macquarie Island); Cook Islands; Federated States of Micronesia; French Polynesia; Guam
Kiribati; Marshall Islands; Nauru; New Caledonia and Dependencies; New Zealand; Niue
Northern Mariana Islands; Palau; Papua New Guinea; Pitcairn Islands; Solomon Islands; Tokelau; Tonga; Tuvalu; Vanuatu; Wallis and Futuna; Western Samoa
(ii) those areas of high seas which are enclosed from all sides by the 200 nautical miles zones referred to in sub-paragraph (i).
(iii) areas of the Pacific Ocean which have been included in the Convention Area pursuant to Article 3.

Article 3 allows any Party to add to the Convention Area those areas under its jurisdiction which fall within certain specified coordinates in the Pacific region as long as no other Party objects. These specified coordinates include the area in the "Pacific Ocean between the Tropic of Cancer and 60 degrees South Latitude and between 130 degrees East longitude and 120 degrees West longitude . . . ." (Convention, Article 3). No areas have been added to the Convention Area under this Article 3.

NOTE: No areas were identified within the fairing and Stage I and Stage II impact zones over which any Party to Convention could have jurisdiction – a prerequisite for adding an area to the Convention Area under Article 3.

Figure 4-1
Impact Zones for Stage I, Stage II, and Fairing



0	1000	2000

Scale in Kilometers (Approx.)

Source: National Geographic Society
Mercator Projection,

Note: Depths are in meters.

TABLE 4-2. SHORTEST EXPECTED DISTANCES BETWEEN LAND MASSES AND ILV STAGE IMPACT ZONES

Land Mass (Country)	Distance Between Land Mass and Stage I Impact Zone (km (miles))	Distance Between Land Mass and Fairing Impact Zone (km (miles))	Distance Between Land Mass and Stage II Impact Zone (km (miles))
Kiritimati Island (Kiribati)	1,073 (667)	1,196 (743)	4,526 (2,813)
Malden Island (Kiribati)	841 (523)	954 (593)	4,255 (2,644)
Hatutu Island (France)	1,027 (638)	660 (410)	2,651 (1,648)
Clipperton Island (France)	4,108 (2,553)	3,748 (2,329)	476 (296)
Cocos Island (Costa Rica)	6,487 (4,032)	6,120 (3,804)	1,994 (1,239)
Galapagos Islands (Ecuador)	5,971 (3,711)	5,605 (3,483)	1,483 (922)
Malpelo (Colombia)	7,091 (4,407)	6,724 (4,179)	2,649 (1,646)

The maximum impact areas[b] of spent Stage I, fairing (assuming the larger 5-m fairing), and Stage II components (including the sleeve adapter) would be 404 m^2 (4,400 ft^2), 177 m^2 (1,930 ft^2) and 127 m^2 (1,380 ft^2), respectively, for any launch. In the context of the expanse of ocean area in each impact zone, the environmental effect of this deposition would be minimal. The 3-sigma impact zones for Stage I, for the fairing, and for Stage II are 1.18×10^9 m^2 (1.28×10^{10} ft^2), 4.71×10^9 m^2 (5.13×10^{10} ft^2), and 1.26×10^{10} m^2 (1.37×10^{11} ft^2), respectively. These areas are where, with 99.67 percent certainty, the components are predicted to fall.[c] Therefore, for any individual launch, only 0.00003 percent, 0.000003 percent, and 0.000001 percent of the ocean area within the impact zone area would be affected by Stage I, fairing, and Stage II debris, respectively. The deposited fairing material from successful launches would initially float and gradually sink as it becomes waterlogged, while stage material would sink and slowly dissolve and be buried in the ocean bottom. These materials are primarily composed of aluminum, steel, or graphite composite, some with small quantities of plastic, ceramic, and rubber products. On the bottom, the debris would become part of the ocean floor habitat much as materials such as old ships, drilling rigs, and tires submerged in coastal waters become substrate and shelter for marine organisms and attract new communities (Chou, et al., 1991).

Over this area of the equatorial Pacific Ocean, residual propellants would be released as spent ILV components fall into the ocean. Table 4-3 shows the quantity of residual kerosene and LOX associated with stage deposition during a successful flight. Residual LOX would dissipate immediately upon release. Residual kerosene would be dispersed into a mist during descent, and all but the largest droplets of kerosene would evaporate within a few minutes. Kerosene that reached the ocean surface would quickly spread on the surface from the effects of gravity, wind, and waves. A circular area with a radius of approximately 130 m (430 ft) would eventually be covered by a visible sheen from approximately 2,750 kg (or 6,050 lbs) of residual kerosene in Stage I (Doerffer, 1992). This estimate assumes that the entire residual amount of Stage I kerosene reaches the ocean surface, and that it would not evaporate.

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[b] The maximum impact area is defined as the largest amount of the sea floor that would be covered by the flattened surface areas of stage or fairing debris.

[c] This impact area is based on a probability estimate that accounts for each component's momentum as well as wind dispersion. For Stage I, the 3-sigma area is estimated to be an ellipse 50 km long and 30 km wide (31 by 18.8 mi; for the fairing, 120 km long and 50 km wide (75 by 31 mi); and for Stage II/Upper Stage sleeve adapter, 200 km long and 80 km wide (125 by 50 mi). For the purposes of this EA, the 5-m fairing is being evaluated as the worst case.

With these assumptions, the kerosene thickness in the center of the circle, after a few days, would be approximately one millimeter (0.05 in) (Patin, 1999; Ramade, 1978; and Lee, 2001). This theoretical approach, however, greatly overstates the area affected. Over 95 percent of this residual kerosene would evaporate within a few hours, while the remainder would disperse in the water column and degrade, such that the ocean environment would return to its initial condition within a few days (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). The area affected by Stage II kerosene would be proportionately less given the smaller volume of residual kerosene.

Although product-specific data are not available on alternative kerosene supplies presently being considered by SLLP, i.e., Boktan from Russia or kerosene from suppliers in the U.S., it is believed that either alternative would have physical and chemical characteristics and environmental effects comparable to the kerosene addressed in this EA. Should SLLP decide to use alternative kerosene supplies at some point in the future, proper environmental analysis will be conducted as appropriate. SLLP will continue to try to improve and optimize the use of the amount of propellants loaded on the ILV. This will serve to further reduce residual quantities of propellants remaining in tanks after engine burn.

TABLE 4-3. PRIMARY PROPELLANTS ASSOCIATED WITH STAGE I AND II FLIGHT AND DEPOSITION

Associated Component	Initial Kerosene (kg (lbs))	Initial LOX (kg (lbs))	Residual Kerosene (kg (lbs))	Residual LOX (kg (lbs))
Stage I	89,773 (197,500)	235,331 (517,728)	2,750 (6,050)	7,250 (15,950)
Fairing halves	N/A	N/A	N/A	N/A
Stage II	22,950 (50,490)	58,703 (129,147)	700 (1,540)	1,800 (3,960)

Recovery Time

The environment would recover from the effects of the residual hazardous material from each launch relatively quickly, and return to its natural condition within a few days. In terms of this recovery time, there would be no indication that a launch had taken place when the next launch occurred (approximately 45 days later under the license applicant's proposed action (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). No other hazardous materials would be released to the environment during this phase of a successful launch; Stages I and II, which consist of metal and small amounts of ceramic, rubber and plastic materials, would sink to the ocean floor and remain in an inert state.

The ILV would consume approximately 414,000 kg (911,000 lbs) of propellant during ascent, and produce carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and water vapor (H_2O) emissions, see Table 4-4. In addition to these main emission products, relatively small quantities of soot and sulfate particles (i.e., fine particulate matter produced in combustion) may be released to the atmosphere (Newman et al., 2001; Fahey et al., 1995). Also, as the ILV plume, which is rich in water vapor, transits the lower layer of High Altitude Tropical cirrus clouds, ice crystals form in the water vapor of the plume and mix with existing ice crystals. This higher concentration of ice crystals makes the contrail visible.

TABLE 4-4. TOTAL EMISSIONS PER LAUNCH

Atmospheric Layer	Altitude* Range (km (mi))	Propellant Consumed (kg (lbs))	Emission Products per Launch in kg (lbs)				
			CO	CO_2	H_2	H_2O	N_2
Lower Troposphere	0.0-2.0 (0.0-1.2)	61,714 (135,771)	17,033 (37,473)	26,907 (59,195)	432 (950)	17,342 (38,152)	0
Free Troposphere	2.0-10.0 (1.2-6.2)	69,100 (152,020)	19,072 (41,958)	30,128 (66,282)	484 (1,065)	19,417 (42,717)	0
Stratosphere	10.0-51.0 (6.2-32)	158,831 (349,428)	43,837 (96,441)	69,250 (152,350)	1,112 (2,446)	44,632 (98,190)	0
Mesosphere and Thermosphere	51.0-292 (32-182)	124,697 (274,333)	33,987 (74,771)	55,508 (25,231)	991 (2,180)	34,226 (75,297)	36 (80)
	Total	414,342 (911,552)	113,929 (250,643)	181,793 (303,058)	3,019 (6,641)	115,617 (254,356)	36 (80)

These emission products are thought to contribute to several types of atmospheric environmental impacts, including global warming, acid rain, and ozone layer destruction. Although CO_2 is a probable contributor to global warming, the amount released by SLLP during a year of operation is much less than the amount of CO_2 normally cycled at the ocean surface (see Section 4.1.3.4; Takahasi, et al., 1997). Launch vehicle operations in general have a negligible effect on acid rain, with effects attributable to the combination of sulfur dioxide, nitrogen oxides, and aluminum with water vapor in the atmosphere. Many studies have been done on the cumulative environmental effects of launches worldwide. The American Institute for Aeronautics and Astronautics convened a workshop to identify and quantify the key environmental issues that relate to the effects on the atmosphere of launches. The conclusion of the workshop, based on evaluation of scientific studies performed in the U.S., Europe, and Russia, was that the effects of launch vehicle propulsion exhaust emissions on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming were extremely small compared to other anthropogenic impacts. SLLP propellants would not generate significant amounts of these substances therefore these launches would have negligible effects on acid rain formation.

Biological Communities and Commercial Activities

The potential effects of successful launches and Stage I and II flight on biological communities and commercial activities are limited to the noise effects associated with the launch; and spent stages and fairing falling on a marine organism, ship, fishing vessel, or aircraft.

Noise Effects on Biological Communities

In terms of noise, steady noise from pre- and post-launch operations (e.g., from ship engines) may reach approximately 70 dB. Research indicates that this level of noise would not have a detrimental affect on any animal that would linger in the area (Shulhof, 1994; Richardson, et al., 1997). In fact, wind speeds of approximately 60 km/hr (37 mi/hr), which occur in the eastern portion of the Pacific Ocean, generate similar levels of noise (i.e., approximately 70 dB) on the open ocean (NIMA, 1998; Cato, 1994).

No significant noise impacts would be expected from the launch because of the relatively short duration of launch noise and the unlikely presence of the higher trophic level organisms near the launch site. Section 4.3.2.1 of the February 11, 1999 EA identified noise from a single launch to be 150 dB at 378 m

(1240 ft), with the equivalent sound intensity in the water at this distance being 75 dB. This reflects the fact that noise generated above the ocean is significantly attenuated by the air-water interface, which protects fish and marine mammals from most above-water noise impacts (Bowles, 1995). Navy research indicates that noise levels of 130 dB in the water are needed before changes in behavior patterns of certain whale species (Sperm and Humpback) are observed (Office of Naval Research, 2000). Other research found that noise of 130 dB might cause humpback whales to move away from the noise source and increase their dive duration. This level of noise did not result in any observed mass strandings or desertion of young (Ocean Studies Board, 1995). This study also found that elephant seal behavior near the sound source was apparently unaffected (Ocean Studies Board, 1995). Some environmental groups assert that noise levels of 140 dB cause whales to change their course and abandon their calves (ENS, 2000a). The Navy is currently preparing an EIS that evaluates the effect of its Surveillance Towed Array Sonar System (STASS) on marine mammals. The STASS generates noise levels of 160 to 180 dB; noise levels that could cause behavioral changes and/or injury to marine mammals, according to the U.S Marine Mammal Commission (ENS, 2000a). The Navy's Draft EIS concluded that the STASS is not likely to adversely affect listed species under the National Marine Fisheries Services (NMFS) jurisdiction, which include marine mammals. On 5 May 2000, NMFS informed the Navy that NMFS was not able to concur with their determination (ENS, 2000b). The Navy's Final EIS has not been released. The noise generated from SLLP's ILV would be diffuse compared to that generated by STASS.

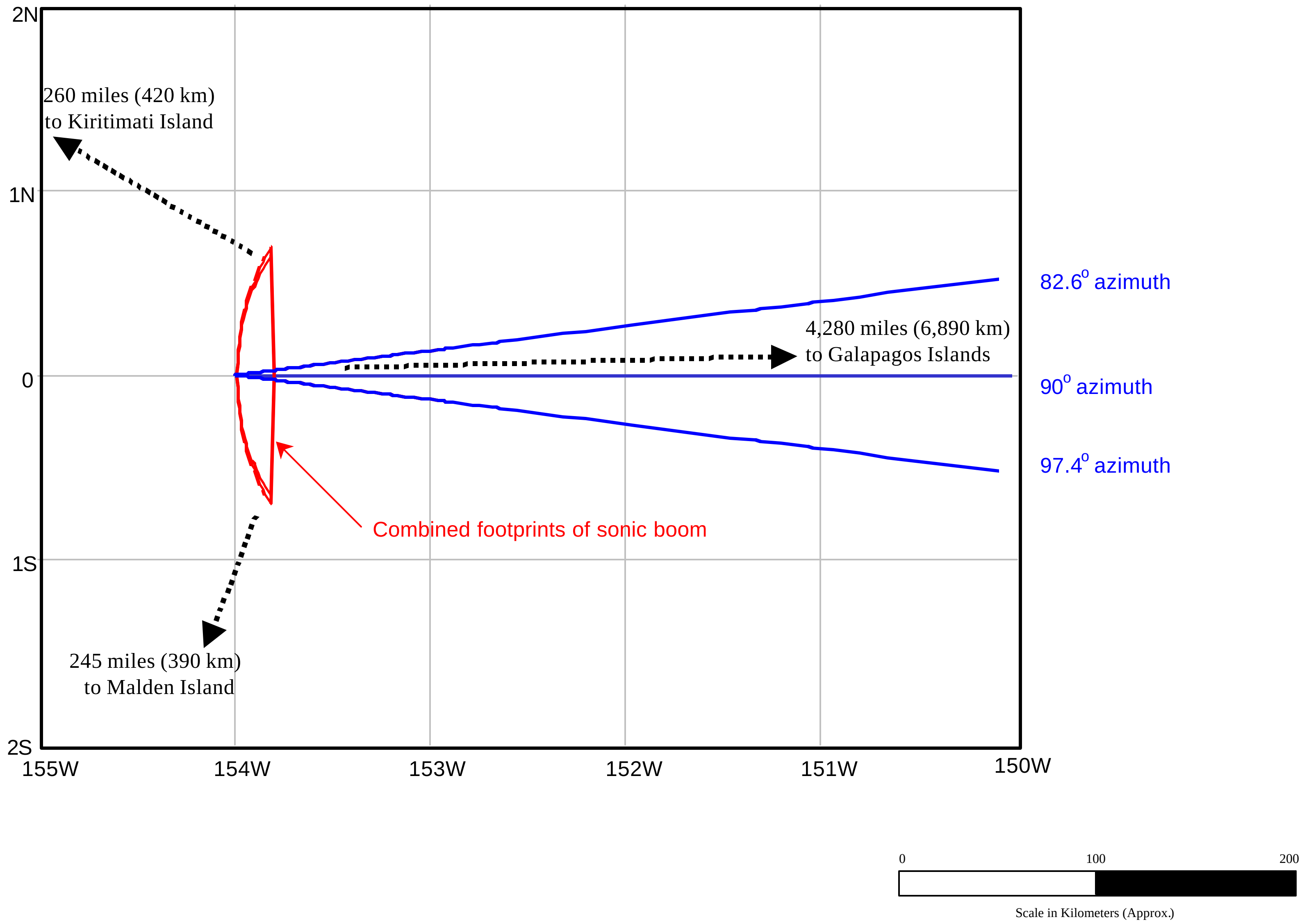
Data suggest that fish and marine mammals will move to avoid chronic high level noise and noise that may increase slowly in magnitude (Office of Naval Research, 2000; ENS, 2000). Fish and marine mammals, however, are not likely to be able to move quickly enough to avoid sudden acute high level noise. The velocity of sound in seawater is approximately 1,500 m/s (4,950 ft/s), or about 4.5 times faster than in air (Taley, 1990).

The decibel scale used to measure acoustic energy or sound is logarithmic (i.e., an increase from 60 dB to 120 dB represents a million times greater level of acoustic energy). The available data indicate that noise levels impacting the ocean environment would need to be much higher than the 75 dB generated by an SLLP Zenit-3SL launch to adversely affect marine life. Further, noise generated by the launch would last less than a minute (i.e., in less than 60 seconds the ILV would be over 10 km (6 mi) in altitude). Finally, as a condition of the launch license, an individual launch would be postponed if a whale or turtle were spotted within 100 m (330 ft) of the LP by visual observers up to 60 minutes prior to launch, at which time automatic launch processes are activated. In the seven launches to date, only one species of concern has been sighted during the entire launch countdown. An endangered species of Hawaiian Petrel was observed as part of the environmental monitoring for Mission 4. A bird was observed on the day before the launch and one-hour after the launch by observers on the ACS. Environmental monitors noted the sighting and submitted the information as part of the launch monitoring report. (See Environmental Monitoring Program Plan (EMPP), found in Appendix G.)

Sonic Booms

A sonic boom would occur when the ILV reaches supersonic velocity during Stage I flight. A sonic boom is caused when an object moving faster than sound (i.e., 1,200 km/hr (750 mi/hr) at sea level) compresses the air in its path. The sound heard at the Earth's surface as a "sonic boom" is the sudden onset and release of pressure after the buildup by the shock wave or "peak overpressure." The change in pressure caused by a sonic boom is only a few kilograms per square meter (pounds per square foot). The footprint of the sonic boom extending from the ILV during supersonic flight is provided in Figure 4-2, which encompasses the sonic boom footprint for all launch azimuths under the license applicant's proposed action. In other words, the effects of a sonic boom for flight on any azimuth within the license applicant's proposed action would be contained within the limits depicted in the footprint in Figure 4-2

Figure 4-2
Sonic Boom Footprint and Distances to Selected Land Masses



The maximum pressures experienced from a sonic boom would be directly under the launch vehicle flight path, and is primarily a function of velocity and altitude. As Figure 4-2 indicates, the sonic boom would occur over the open ocean far from any of the Oceanic Islands. The distance between the sonic boom footprint and the closest landmass (i.e., Kiritimati Island) is 420 km (260 mi). The effects of the sonic boom would be rapidly attenuated by the air-water interface (i.e., the acoustic energy associated with the sonic boom will be partially absorbed as it goes from the air into the water surface, lessening the effect) (Bowles, 1995). Thus, it would not have any significant adverse effects on marine organisms that happen to be in the area other than a startle reaction. A startle reaction may cause an adverse effect in a threatened and endangered species; however, little information on the physiological impacts of the startle effect is available for marine organisms in the open ocean. No physical harm to animals or ships at sea level would occur because of the altitude of the launch vehicle and its vertical acceleration (USAF, 1996).

Limiting Potential Impacts from Falling Stages and Fairing

The likelihood of spent stages and fairing striking a marine organism, ship, fishing vessel, or aircraft and preventative measures taken to avoid such an event are described in Sections 4.3.2.1 and 4.5.5, respectively, of the February 11, 1999 EA. (See Appendix A.) Coordination efforts to reduce this possibility are further detailed in the EMPP (Revision 1, August 21, 1999), which is attached to this document as Appendix G. In summary, for each launch, SLLP gives advance notice to the FAA (Central Altitude Reservation Function), the USCG (14th District), NIMA, and the U.S. Space Command (USSC). To coordinate air, marine, and space traffic, these organizations routinely issue necessary information through well-established communication channels. For vessels without receiving equipment, standard notices are delivered by fax to Kiribati government authorities and regional fishing fleet and tour operators for distribution and posting. Notices are broadcast using U.S. Government protocols via INMARSAT-C, Pacific Ocean Region satellite on Safety Net channel at 10:00-10:30 and 22:00-22:30 GMT each day starting 5 days prior to each launch. The notice is also broadcast on frequencies in the high frequency (HF) band by USCG, Honolulu. The notice is distributed to Christmas Island local authorities and tour boat operators for posting and distribution; the Ministry of Information, Communication, and Transport for posting; and the operators of regional fleets at their headquarters, e.g., national and industry operators. In addition, the launch criteria prescribe that no launches would be conducted unless all vessels are clear of the predetermined safety zones surrounding the LP (visual observations would be taken up to 30 minutes prior to launch). Visual and radar sensors would be used to verify the absence of vessels in this zone. Therefore, the chance of spent stages or fairing striking a marine organism, ship, fishing vessel, or aircraft is very remote.

4.1.1.3 Upper Stage Flight Over the Oceanic Islands and South America

Upper Stage and payload flight would progressively transit over open ocean waters, the Oceanic Islands, and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes.

Atmospheric Processes

The only environmental effect associated with Upper Stage flight of a successful mission is the combustion or venting of relatively small quantities of Upper Stage and payload propellants at high altitudes that are well above the range for potential atmospheric impact. The Upper Stage would achieve a low Earth orbit at an approximate altitude of 180 km (112 mi), at which point motors would be fired as needed to position the payload in the specified orbital parameters.

Future launches may use alternatives to the Russian kerosene (RP-1) presently used on the Upper Stage of the Zenit-3SL. Specifically, a petroleum hydrocarbon product called "Boktan" that is manufactured in Russia may be used to enhance ILV performance by increasing thrust and lift capacity. Kerosene from suppliers in the United States may be used to lower operating costs. The analyses presented in this EA, therefore, anticipate the possible substitution of Russian RP-1 kerosene with either of these alternatives. The U.S. kerosene is chemically equivalent to the RP-1 kerosene presently used by SLLP. The Boktan product, however, is a different chemical that needs to be considered further. See Appendix E for a comparison of chemical and physical characteristics of these propellants. Should SLLP decide to use either U.S. kerosene or Boktan at some point in the future, proper environmental analysis will be conducted as appropriate.

While Boktan requires somewhat greater personnel safety precautions (e.g., gloves and protective clothing) during handling than kerosene (based on their respective toxicity classes), its fate and effect during use or in the event of a spill are expected to be similar to kerosene or other low molecular weight hydrocarbon products. Specifically, Boktan would be used in equivalent quantities as an engine fuel and it would have the same emission products (e.g., CO, CO_2, H_2, and H_2O) as kerosene when burned. Boktan's rates of dispersion and evaporation in the open ocean environment if spilled or released would be somewhat greater given that its boiling, melting, and flash points are all somewhat lower than kerosene (i.e., resulting vapor pressure would be somewhat lower as well). Therefore, it is likely that the fate (i.e., ultimate break down and chemical form in the environment) and effect of Boktan in the environment would be very similar to those of the currently used Russian kerosene. Should SLLP decide to use Boktan at some point in the future, proper environmental analysis and review will be conducted as appropriate.

The February 11, 1999 EA (Section 4.3.2.1) solely considered the use of MMH as an Upper Stage propellant, which is the propellant used in six SLLP launches to date (the seventh mission used UDMH and N_2O_4). It is conceivable that UDMH (both U.S. and Russian produced) would be used in future launches proposed in this action. The properties of UDMH are summarized in Appendix E. Although it has a different molecular structure in the hydrazine family of chemical compounds, UDMH is equivalent to MMH in terms of its use in the Upper Stage. UDMH quantity, behavior, fate, and effect relative to the environment during a successful launch would also be equivalent as it is expended at very high altitudes beyond the range of potential atmospheric impact.

Once in the target orbit, the Upper Stage would be separated from the satellite payload, its gases and propellants would be vented or depleted into space, and it would be put into a final disposal orbit where it would remain for decades or longer.

4.1.1.4 Post-Launch Operations

Debris remaining on the LP would be collected, identified as to source (for compliance with U.S. Department of State Technology Transfer requirements), and disposed of in accordance with the International Convention for the Prevention of Pollution (in compliance with MARPOL 73/78) or brought back to Home Port for proper disposal. As part of post-launch cleaning, particulate residues (i.e., scorched deck paint) would be swept and washed off the deck with freshwater, and the deck would be repainted while at sea. The quantity of such wash water is expected to be a few kilograms/pounds.

4.1.2 Environmental Impacts of Possible Failed Mission Scenarios

A possible failed mission can occur at the LP, during Stage I or Stage II flight, or during Upper Stage flight. In most cases, a failure would result from a detected deviation between the programmed flight path parameter (e.g., pitch, yaw, roll) and the actual flight parameters as monitored by ILV sensors. If flight deviations exceed established limits, the thrust termination system would terminate the flight. Failure of the onboard computer systems could also result in thrust termination and loss of the mission. SLLP has projected launch reliabilities of 0.982 for Stage I flight, 0.956 for Stage II flight, and 0.974 for Upper Stage flight (SLLP, 2001). For the purposes of conducting debris risk analyses the FAA specifies that for launch vehicles "with fewer than 15 flights, a launch operator shall use an overall launch vehicle failure probability of 0.31." 14 CFR § 417.227(b)(6)(i) For launch vehicles "with at least 15 flights, but fewer than 30 flights, a launch operator shall use an overall launch vehicle failure probability of 0.10 or the empirical failure probability, whichever is greater." 14 CFR § 417.227 (b)(6)(ii) For launch vehicles "with 30 or more flights, a launch operator shall use the empirical failure probability determined from the actual flight history." 14 CFR § 417.227 (b)(6)(iii)

4.1.2.1 Possible Failure at the Launch Platform

Section 4.3.4.1 of the February 11, 1999 EA considered an explosion on the LP as representing a worst-case occurrence of Stage I and II failure. A possible failure at the LP would likely result in a cascading explosion of all ILV propellants. The explosions would scatter pieces of the ILV, and perhaps pieces of the LP, as far as three kilometers (two miles) away (the LP is designed to survive an explosion of the fully fueled launch vehicle). A smoke plume would rise and drift downwind some distance before dissipating. In the course of about one minute, the entire matter and energy of the ILV would be dispersed in the environment in a relatively concentrated area of the ocean. Environmental effects would include intense heat generated at the ocean surface; debris and noise released during the explosion; emissions released to the atmosphere; and the subsequent cleanup needed on the LP. Despite this intense, short-term, and localized disruption, there would be no discernible long-term impact to the environment. The fuels not consumed in the explosion would evaporate or become entrained in the water column and would eventually be degraded by microbial activity and oxidation (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). The areas of plankton lost due to heat or toxic effect would be re-colonized as currents redistribute the surface waters (Grigg and Hey, 1992). Section 4.3.4.1 of the February 11, 1999 EA concluded that the environmental effects of a failure at the LP would be short-term and localized relative to the scale and character of the ocean environment. For the license applicant's proposed action, the environmental effects of a failure at the LP would be the same as described in the February 11, 1999 EA.

Launch Abort Scenarios

There is also the potential for a launch abort at the LP (i.e., when a countdown is interrupted or no launch occurs, which is technically not a failure). In general, a launch would be aborted if equipment malfunctions or unresolved deviations of ILV parameters occur just before launch. Due to the inherent complexity of the ILV, a deviation in any number of factors could trigger an abort, and the extent to which propellants need to be safeguarded would vary based on the time prior to launch that the abort occurs. In all cases, however, the resulting contingency measures initiated by SLLP would follow established routines to stabilize the ILV on the LP. A worst-case abort, which would occur three seconds prior to launch, involves the largest quantities of propellant and the most detailed contingency measures. An abort scenario would involve draining small quantities of propellant into the flame bucket where it would evaporate due to wind effects. In addition, the pyrophoric fluid that initiates kerosene ignition would be burned according to SLLP's operating procedures. The ILV would be returned to a horizontal position in the LP hanger, and the propellant reservoirs from the Stage I engine would be drained into containers for later disposal at the Home Port as a hazardous waste.

An abort at three seconds prior to launch occurred during the SLLP Mission 6 launch planned for January 8, 2001. Visual observations by safety personnel during that event reported that, when drained, the pyrophoric fluid combusted instantly upon exposure to air in a sporadic stream approximately 4 m (13 ft) long, over several minutes. The draining of kerosene in engine propellant lines occurred as described in Section 4.3.1 the February 11, 1999 EA. Specifically, approximately 70 kg (150 lbs) of kerosene from the Stage I engine splashed onto the exhaust deflector, a large steel structure positioned under the ILV, and evaporated over the course of several hours from the effects of a steady breeze. No hazardous material was observed contacting the ocean surface. The emissions from the propellants that burned or evaporated during this process were dispersed into the atmosphere. These emissions would pose less environmental risk than those from a successful launch because much less of the propellant would be combusted during an abort event.

This is considered the worst-case abort scenario since before this point in the countdown, fewer hazardous materials would be involved, while after this point, the starting fluid would have initiated ILV ignition and flight. After this point, the event would take the form of either failure on the LP (see above) or during flight (Sections 4.1.2.2 and 4.1.2.3 below). As this observed event represents the worst-case abort scenario and did not result in significant environmental impacts, this or similar potential launch aborts would not be expected to significantly affect the environment.

The environmental impacts of failed missions that occur during Stage I or II flight or during Upper Stage flight, however, are evaluated below as such failures would affect a broader geographic area due to the proposed range of azimuths. The effect of successive launch failures is also considered in Section 4.1.3.6.

4.1.2.2 Potential Failure During Stage I and II Flight Over Open Ocean

An ILV failure moments after the ILV leaves the deck of the LP could also be considered a worst-case scenario since the propellant quantities involved would still be near a maximum at the onset of flight, and the failure would occur over the ocean rather than on the LP. A possible failure at this stage of flight would put all unexpended propellants, other hazardous materials, and ILV hardware into the environment in a more concentrated area than would occur during a successful flight. The quantity of hazardous material and debris reaching the ocean surface would depend on when in the flight the failure occurred (i.e., the longer the flight before failure, the less propellant would be onboard the ILV and available to potentially reach the ocean surface).

Possible failure at this point of the launch could occur in two ways: explosive failures and thrust termination failures. The mass and character of hazardous material (including the various propellants) and debris that would reach the ocean would depend on the type and time of failure during a launch.

Explosive versus Thrust Termination Failures

Potential explosive failures (marked by the sudden destruction of propellants and the ILV during flight) would result in the scattering of ILV parts and the immediate consumption by burning of most if not all of the hazardous materials incorporated by or contained in those parts. In contrast, possible thrust termination failures (i.e., one in which a deviation in flight triggers engine cutoff) would result in the ILV losing upward and forward momentum and falling toward Earth. In this case, an ILV early in Stage I flight would likely fall intact and rupture on the ocean surface, while later in Stage I flight and during all of Stage II flight, the ILV would begin to tumble within seconds and break up due to stresses on the structure. Explosions may also occur during thrust termination if, as the ILV breaks up, flammable materials become exposed to hot engine parts and ignite. If an explosion does not occur, the extent to which ILV materials would reach the Earth's surface would depend on the altitude and speed of the ILV at the time of thrust termination.

Possible Failure Near the Launch Platform

The worst-case scenario during initial ILV flight would be a thrust termination failure within 20 seconds of the ILV leaving the LP and the ILV falling intact and rupturing on the ocean surface. Regardless of when within the first 20 seconds the failure occurs, the ILV flight would continue until the twentieth second at which time the thrust termination system would automatically end the flight. This delayed termination has been automated to ensure that this type of failure does not damage the LP and to ensure that the ILV falls safely away from the ACS, which is positioned approximately five km (three mi) from the LP. At this point in flight, most of the propellant is unburned and virtually all of the ILV mass of propellants (see Table 4-3), other hazardous material, and components would be released into the environment in a concentrated area.

A possible failure near the launch platform would be worse than either an explosive failure or a thrust termination failure in which the ILV explodes later in the flight. In the case of a failure involving an explosion, most of the ILV would be consumed, destroyed, and scattered in a series of cascading explosions, and the propellants and other flammable materials would be burned before reaching the ocean surface. A thrust termination or explosive failure later in the launch may have less environmental impact (depending on the impact location). During such a failure later in flight more of the debris and virtually all of the propellants would be incinerated or evaporated and not reach the ocean surface, while those debris or propellants that would reach the ocean surface would be more dispersed. In general, larger and more concentrated amounts of ILV material and debris released during a failure would have a proportionately greater impact and take more time to dissipate and break down in the environment.

Effects of a Possible Failure During Stage I or II Flight

For the license applicant's proposed action, the scenario of possible Stage I or II failure, and especially the worst-case scenario of possible thrust termination failure during the first 20 seconds of flight, would occur over the east-central Pacific Ocean, well away from the Oceanic Islands and South America. Even if a failure caused a deviation from the intended flight plan, the deviation prior to thrust termination would not be so great as to have any environmental effects significantly closer to the Oceanic Islands than the normal debris deposition areas of a successful flight (see Table 4-2). Therefore, the debris from the ILV would fall into the deep waters of the open ocean far from any Oceanic Islands. The debris, which includes metal and composite components that incorporate small amounts of rubber, plastics, and ceramics, is largely inert and would settle to the ocean bottom as described in Section 4.1.2.1 and become an inert part of the seafloor ecology (Chou, 1991).

A possible failure during Stage I or II flight would result in the release of propellants and other hazardous materials (see Section B.3 and Table B.3-1 of the February 11, 1999 EA). In addition to the main propellants, kerosene (or Boktan) and LOX, small quantities of the propellants MMH (or UDMH) and N_2O_4 would be released, as would even smaller amounts of explosive compounds and metals present in release mechanisms and batteries.

The primary effects of a failure during Stage I or II flight are threefold:

- Release of emissions to the atmosphere.
- Release of propellants and other hazardous material to the ocean.
- Likelihood of Stage I or II debris falling on marine organisms, marine vessels, or aircraft.

Each of these effects is evaluated below for the worst-case scenario.

Release of Hazardous Materials, Including Emissions, to the Atmosphere

Vapors and aerosols (from evaporating propellants including LOX, kerosene (or Boktan), MMH (or UDMH), and N_2O_4) and combustion reaction products (primarily O_2, CO, CO_2, H_2, H_2O, nitrogen oxides (NO_x), including potentially small quantities of soot and sulfate particles) would disperse with the prevailing winds. Vapors would react with solar energy, break down to form smog and dissipate into the environment. Aerosols and liquid drops large enough to fall to the ocean surface would disperse with surface currents and break down under the influence of solar energy and microbial action (primarily to CO_2 and H_2O). As combustion during a failure is uncontrolled and inefficient, not all propellant mass would be converted to energy and some particulate residues would travel with the wind, settle on the ocean surface some distance from the point of failure, and break down into the same more basic compounds.

Release of Hazardous Materials to the Ocean

Potential impacts from the release of hazardous materials to the open ocean as a result of a possible failure during Stage I or II flight would be the same as those discussed in Section 4.1.1.2, "Oceanography and Atmospheric Processes."

Kerosene can be toxic to marine organisms, and it would likely affect plankton on the ocean surface. Overall plankton mortality, however, would be minimal because the affected area would be small relative to the scale of the ocean, and plankton population densities are naturally discontinuous and concentrated below the surface (Murray, 1994). Plankton re-colonization of the affected area would occur within a few days to a week in even the most directly affected area as surface waters move and mix under the effect of currents and winds (Grigg and Hey, 1992). Accordingly, the surface and ocean environment would return to pre-launch conditions within a week or so, even considering the most significant aspect of this worst-case failure. As such, there would be no indication of a failure by the time the next launch would occur. As discussed in Section 4.1.4.6 of this EA, this duration would be four to 12 months, considering the mandatory investigation that would follow any failure.

Comparable physical and chemical processes would be expected if the present kerosene product is replaced by Boktan or another kerosene. This determination is based on product data presented in Appendix E. Should SLLP decide to use either U.S. kerosene or Boktan at some point in the future, proper environmental analysis will be conducted as appropriate.

The hazardous materials in the Upper Stage and payload (primarily MMH (or UDMH) and N_2O_4) that would be released to the environment during a failure, would have slightly greater initial toxic effect than released kerosene because they are more volatile and reactive (see Appendix E and discussions in this section above). UDMH and MMH are both hydrazine fuels (a type of launch vehicle and spacecraft fuel used in hypergolic propellant systems) that have different chemical and physical parameters (e.g., boiling point, specific gravity, vapor pressure, flash point). The two fuels, however, are similar in terms of their reactivity, products of combustion (based on using N_2O_4 as an oxidizer), exposure limits and United Nations and United States Department of Transportation hazard classification. The overall impact from these materials would be considerably less than the impacts from kerosene because smaller quantities would be used.

Compared with the worst-case failure scenario (i.e., thrust termination failure within 20 seconds of flight), the return to pre-launch conditions for Stage I or Stage II failure would be somewhat faster (i.e., hours and days rather than days to a week) given the decreasing mass of propellants and other hazardous material onboard the ILV as the flight progresses (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999).

Risk of Debris Falling on Marine Organisms, Vessels, or Aircraft

There is likely to be more debris reaching the Earth surface from a failure than from a successful mission. Also, and as indicated above, a thrust termination failure without an explosion would result in the most debris (i.e., potentially the entire ILV), while a failure late in Stage II flight would introduce less debris as some of the ILV would vaporize or burn before reaching the Earth's surface. In general, therefore, increasing altitude and speed would result in more debris being burned up during descent, and debris that does reach the ocean surface from a high-altitude Stage II failure would be inert after being subjected to the intense heat generated while re-entering the upper atmosphere. The surviving debris, which would cool during the descent through the lower atmosphere, would still initially be hot to warm. The debris would cool to ambient ocean water temperature within minutes of contact, and would have a negligible effect on any marine life.

The risk of ILV debris falling on marine organisms is remote given the launch criterion that a launch would not occur if whales or sea turtles are observed in the area surrounding the LP prior to launch. As with Stage I or II deposition during a successful flight, however, there is a chance that the debris and/or hazardous material from a failure later in flight may fall on a marine organism at the ocean surface. Because of the relatively low population densities of marine organisms (especially marine mammals) in this region, and low probability of an organism being present at the ocean surface (e.g., during breaching) (Kasamatsu, et al., 1995), such an impact would be very unlikely. The probability of debris falling on a marine vessel or aircraft during Stage I or II failure is discussed in Section 4.1.2.3 of this document, and is calculated to be between 0.6×10^{-8} to 1.1×10^{-13}.[d]

4.1.2.3 Potential Failure During Upper Stage Flight Over the Ocean, Oceanic Islands, or South America

Possible failure during flight of the Upper Stage could conceivably occur at any point as the Upper Stage progressively transits over the open ocean, the Oceanic Islands, and the northern part of South America. Given the speed and altitude of the Upper Stage during this period, a failure during any point in Upper Stage flight would result in most of the material components and all of the propellants being heated in the atmosphere and vaporized or burned from frictional effects before reaching the Earth's surface. Approximately 42 components from the Upper Stage and payload could survive reentry friction and reach the Earth's surface. These objects range from 0.04 m (0.13 ft) to 1.2 m (3.9 ft in size, and 0.3 kg (0.7 lbs)) to 90 kg (205 lbs) in mass (see Table 4-5). The actual amount of debris that survives depends on the time of failure during the flight (i.e., more debris would survive a failure that occurs earlier during the flight).

As is the case for possible Stage I and II failures discussed above, a possible Upper Stage failure could occur as an explosion (where propellants in the Upper Stage suddenly combust) or a thrust termination (where acceleration ceases and the remaining ILV components begin to fall). In both types of failure scenarios, the hazardous materials associated with the Upper Stage, the satellite payload, and their connecting components would be rapidly consumed (in an explosion) or released and dispersed (as the ILV components tumble and break up in the fall to Earth). In this manner, only the ILV components that would survive the fall to Earth (Table 4-5) would affect the environment.

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[d] *Draft: Standard Geosynchronous Transfer Orbit Missions, Launch Operator License Application,* Document D688-10739-1, SLLP, October 2000.

TABLE 4-5. DEBRIS EXPECTED FROM UPPER STAGE AND PAYLOAD REENTRY

DM-SL Debris Surviving Re-entry			
Components	**Size** m (ft)	**Mass** Kg (lb)	**Area** m^2 (sq. ft)
Uncooled nozzle	1.2x1.0 (3.9x3.3)	12 (26)	1.2 (13)
Engine frame	0.4x1x1 (1.3x3.3x3.3)	14 (31)	0.4 (14)
Combustion chamber	0.14x0.25 (0.46x0.82)	13 (29)	0.035 (0.38)
Cooled nozzle	1x0.6 (3.3x2.0)	40 (88)	0.6 (6.6)
Turbo pump	0.75x0.25 (2.46x0.82)	31.5 (70)	0.188 (2.02)
Tank valves (2)	0.12x0.2 (0.39x0.66)	9 (20)	0.024 (2.6)
Submerged bottle	0.48 dia. (1.57)	16 (35)	0.18
Oxidizer supply unit	0.75x0.3 (2.46x1.0)	35.5 (78)	0.22 (2.46)
Gas generator	0.6x0.1 (1.97x0.3)	19 (42)	0.06 (0.59)
Batteries (6)	0.5x0.5 (1.6x1.6)	90 (205)	0.25 (0.59)
Fuel supply unit	0.4x0.2 (1.3x1.7)	25.5 (56)	0.08 (2)
Multiple start unit	0.365 dia. (1.197)	18 (40)	0.10
Bolts – titanium	0.04x0.014 (0.13x0.045)	1.5 (3.3)	0.0006 (0.006)
L-brackets – titanium	0.13x0.25 (0.42x0.82)	0.30 (0.7)	0.033 (0.34)
Payload Debris Surviving Reentry			
Liquid apogee motor	0.56x0.028 (1.84x0.09)	3.8 (8.4)	0.02 (0.2)
5-lbThrusters (12)	0.3x0.08 (1.0x0.26)	2.4 (5.3)	0.02 (0.3)
Battery (4)	0.52x0.5 (1.71x1.6)	73 (161)	0.26 (2.7)
Fuel tanks (4)	0.90 dia. (3.0)	60 (132)	0.63 (6.9)
Propulsion/ACS assembly (equip)	0.90 dia. (3.0)	58 (128)	0.63 (6.9)

Effects of Debris, Including Hazardous Materials, in Open Ocean

An Upper Stage failure has the potential to affect the open ocean, with the impacts being less than those described in Section 4.1.2.2 because most of the material components and all of the propellant would vaporize or burn. Only inert materials, such as durable metals in engine components and batteries, would reach the Earth's surface.

Several types of batteries (i.e., nickel-cadmium, nickel-hydrogen, and silver-zinc), are used in the Upper Stage payload unit, and they would fall to Earth during Stage I, Stage II, and Upper Stage failures. These types of batteries are widely used (e.g., consumer electronics) and are not unique to the space industry. The batteries contain relatively small volumes of potentially toxic chemicals, which would be released into the environment under the various failure scenarios. Specifically, batteries would either fall into the ocean if the batteries do not rupture during Stage I or II failure, or partially disperse in the atmosphere when ILV structures containing batteries rupture during Stage II or Upper Stage flight. In the latter situation, some portion of the battery material would fall to the Earth's surface.

Nickel-cadmium and silver-zinc batteries use potassium hydroxide as an electrolyte between the two metal plates in each battery. Potassium hydroxide is a very corrosive chemical (pH of 13.5). Once in contact with the ocean, an acid-base reaction would quickly occur that would form a potassium based salt, which is not toxic to the environment (Pankow, 1991). Any remaining potassium hydroxide would dissipate in the ocean since it is soluble in water. Nickel, zinc, and cadmium are naturally occurring metals found in trace amounts in ocean water (Eisler, 1998; Eisler, 1985). Silver is most commonly found deposited as a mineral ore, but as a result of various anthropogenic sources (e.g., smelting operations) is now commonly found in trace amounts in the open ocean (Eisler, 1996). The small amount of these metals present in the batteries would gradually disperse.

In the event of a failure during Stage II or Upper Stage flight, the batteries would rupture either from the explosion or from the frictional forces encountered in their descent. Although the battery casings would be expected to survive the reentry, the potassium hydroxide would likely vaporize and react with water vapor present in the atmosphere, again forming a non-toxic salt.

The overall effect on the open ocean from batteries and other surviving debris would be minor, as the hot to warm debris would immediately cool, sink, and come to rest on the ocean floor. An Upper Stage failure, however, also has the potential to impact Oceanic Islands (i.e., the Galapagos Island group, Malpelo Island, or Cocos Island) and the portions of South or Central America that are located within the ILL overlay area (see Figure 3-1). In the unlikely event of an Upper Stage failure, the potential impacts would be small but could include effects from debris falling on:

- Marine organisms,
- Coral reef communities,
- Terrestrial communities on oceanic islands,
- South American habitats, and
- Vessels, aircraft, or humans.

Each of these potential environmental effects is evaluated below.

Debris Impacting Marine Organisms

There is a very slight chance that Upper Stage debris may strike marine organisms. The effects associated with an Upper Stage failure would be less than that for a Stage I or II failure, because most of the components and all of the propellants would burn up or be vaporized before reaching the ocean surface; consequently, there would be less material available to fall on or affect marine organisms. In general, the population density of most marine organisms is low throughout much of the area of concern. The lack of microhabitats and decreased solar energy inputs at necessary water depths limits the diversity and density of marine organisms in the deep ocean (Rex, 1981). Seasonal migrations of Southern minke whales and sharks are relatively dispersed in the eastern Pacific Ocean while right, humpback, and gray whales migrate along the shore, congregate in nearshore breeding areas, and are rarely found in the open ocean (Kasamatsu, et al., 1995). There are, however, particular areas (such as near or on the Oceanic Islands and upwelling boundaries) where population densities would be more variable and potentially higher due to localized increased primary productivity attributable to nutrient and mineral levels (Barber, 1996). On the whole, however, the impact of debris alone falling on individual organisms would be negligible at the population level.

There is a remote possibility that debris may fall on a marine animal (e.g., whale, seal, or turtle) that is listed as a threatened or endangered species by the IUCN or USFWS (see Table 3-2). For the vast majority of the open ocean that constitutes the affected environment of the license applicant's proposed action, however, population densities of these species are very low; the probability of debris falling on one of these species is remote. Although their populations are generally higher near the oceanic islands and where upwelling occurs, they occupy a very small percentage of the surface area of the equatorial Pacific Ocean based on estimates of population sizes and survey data (Hill, et al., 1990). In addition, these species are highly mobile and occupy the ocean at varying depths. An individual would need to be at or near the ocean surface and within the impact zone (e.g., while breaching) to risk injury from falling debris.

Debris Impacting Coral Reef Communities

As described in Section 3.2.1.4, coral growths and reefs are relatively small, poorly developed, and of discontinuous distribution in the eastern equatorial Pacific Ocean. This is generally attributed to low water temperatures, low salinity, high nutrient loads, natural bioerosion, and storm disturbances. Nearshore steep slopes also limit the amount of area suitable for underwater coral platforms (Cortes, 1997). Cocos Island has the only relatively well-developed coral reef in the area affected by the license applicant's proposed action and it is, therefore, considered here in terms of possible impacts to coral.

The Cocos Island reef system would only be susceptible to damage in the Upper Stage failure scenario because Stage I and II failures would occur far to the west of Cocos Island. If an Upper Stage failure occurs during an overflight of Cocos Island, the probability of debris falling on the coral reef at Cocos Island is estimated to be 1.4×10^{-8}, based on a reef area of approximately 15 km^2 (5.8 mi^2) (see Figure 3-8). This calculation overestimates the true probability in that it assumes that the entire reef system area is densely filled with coral growths when it is actually discontinuous (Bakus, 1975). Further, corals near the Oceanic Islands of the eastern Pacific Ocean and off the western shore of Central America have undergone a dramatic decline in recent years, with large areas of coral dying or becoming diseased (Camoin and Davies, 1998).

Corals at Cocos Island are found from just below the water surface to depths of approximately 30 m (99 ft) (Bakus, 1975). Debris from a possible Upper Stage failure could strike an area of healthy coral and damage or dislodge the coral. Because the debris would quickly decelerate during its initial transit through the water, deeper coral areas would sustain less damage. Some inferences may be drawn on the potential effects of Upper Stage debris striking coral from studies in which coral were intentionally damaged by hammer strikes (Syms, 2000) or surficial scrapes (Hall, 1997). These corals showed relatively rapid commencement of recovery within a year or so, as did the associated reef communities. If the foundation platform is undamaged new growth would replace the dislodged coral within decades (Pearson, 1981; and Jaap, 1984). Bioerosion, which is naturally prevalent from time to time, would further jeopardize coral growth and reef recovery in such situations (Reaka-Kudla, 1996). In any event, the probability of debris striking coral reefs is remote.

Recovery from a possible failure that affects coral would require at least several years or more. Because of the discontinuous nature of the coral and the size of the predicted surviving debris is relatively small (see Table 4-5), damage from this failure scenario would be extremely unlikely, would remain very localized and would not threaten the reef system itself.

As discussed in Section 3.2.1.4, Malpelo Island and the Galapagos Islands have even more discontinuous, solitary coral growths with little reef development. Therefore, the risk of falling debris striking living coral reefs at these islands would be commensurately less than at Cocos Island. If coral at Malpelo Island or the Galapagos Islands were affected, the impacts to and recovery of individual coral would be comparable to those described here for Cocos Island.

Debris Impacting Terrestrial Communities on Oceanic Islands

There is also the potential for debris from a possible Upper Stage failure to land on an Oceanic Island (i.e., Malpelo, Cocos, or one of the Galapagos Islands) (see Table 4-6). The debris would be inert after being subject to the intense heat generated while re-entering the upper atmosphere. The surviving debris, which would cool during the descent through the lower atmosphere, could initially be hot to warm to the touch, but the debris would not present a risk of fire. Of the islands involved, the Galapagos and Cocos Islands in particular have notable diversities in terrestrial plant and wildlife species, while Malpelo Island is steep and rocky with relatively less diversity or abundance in terrestrial plant or wildlife species.

As indicated in Table 4-5, approximately 42 components totaling less than 10 m^2 are predicted to survive reentry. The combined size of these components represent less than 0.0000001 percent of the land area of the Galapagos Islands, 0.0005 percent of Cocos Island, and 0.0006 percent of Malpelo Island. The chance of the debris striking a plant or animal is remote. If debris struck a terrestrial organism, however, it could be injured or killed. There is a remote chance that a threatened or endangered species could be hit by falling debris. In such an unlikely event, replacement in terms of population dynamics would depend on the species' abundance, reproduction characteristics, and recruitment success.[e]

The probability of debris landing on the Oceanic Islands would be very low (see Table 4-6), the risk of damage to an island habitat or harm to any individual member of a resident species would also be very remote, and any possible impact would be limited in extent. Taking Cocos Island as an example from Table 4-6, most azimuths within the range in the license applicant's proposed action would present virtually no risk of debris landing on Cocos Island. In fact, azimuths of 83.00^o to 83.28^o and 84.50^o to 97.00^o are far enough away from the island that their ILLs would not overlay it at all. Only with azimuths of 83.29^o to 84.49^o would the Upper Stage overfly or the ILL overlay Cocos Island, thus presenting a probability that should a failure of the Upper Stage occur, some debris might survive and fall on the island.

[e] In this instance, recruitment success refers to the ability of one member of a species to convince another individual to behave in a desired manner.

TABLE 4-6. PROBABILITY OF UPPER STAGE DEBRIS FALLING ON AN OCEANIC ISLAND DURING A SINGLE LAUNCH

Oceanic Island	**Azimuth Associated With**			**Dwell Time[a] (sec)**	**Probability of Debris Falling on an Island**
	ILLs do not overlay island(s)	ILLs overlay island(s) but less than maximum dwell time	Island(s) directly overflown with maximum dwell time		
Galapagos Islands (as a group) [b]	82.6º to 87.47º and 92.22º to 97.4º			0	0.0[c]
		87.48º to 90.84º and 90.86º to 92.21º		Between 0 and 10.61	Less than 0.00067
			90.85º	10.61	0.00067
Cocos Island	82.6º to 83.28º and 84.50º to 97.4º			0	0.0
		83.29º to 83.89º and 83.91º to 84.49º		Between 0 and 0.15	Less than 0.0000094
			83.90º	0.15	0.0000094
Malpelo Island	82.6º to 85.07º and 86.36º to 97.4º			0	0.0
		85.08º to 86.04º and 86.06º to 86.35º		Between 0 and 0.03	Less than 0.0000019
			86.05º	0.03	0.0000019

[a] Dwell time can be considered the amount of time when the Upper Stage is over the island. More technically, it is the amount of flight time when the Instantaneous Impact Point (IIP) (based on a speed of 33,000m/s and a failure probability of 6.28×10^{-5}/sec) traverses the island.
[b] For Galapagos Islands (as a group), assumes debris would land on an island rather than in inter-island water.
[c] As a statistical concept, the probability cannot be zero.

In applying these data to the Galapagos Islands, which possess the greatest variety of habitat types and species among the islands considered in this EA, some general observations can be made. Extensive parts of the islands are very arid and devoid of vegetation or much soil; this is especially true of the steep flanks and young lava flows that usually extend to the sea from the numerous volcanic peaks and ranges. Also dominant on the islands are extensive areas that, while very arid, are more moderate or level in slope, which allows established soils to support desert vegetation including cactus, brush, and grasses. Also present, but less common, are relatively moist areas marked by lush grasses and trees. Most fauna are concentrated near the sea or in the moist habitats due to their reliance on associated nutrients.

Debris could directly fall on resident reptiles, birds, or mammals, or damage habitat due to the initial force of contact. Such debris impacts could damage vegetation, cause cracks and depressions in harder material (e.g., volcanic rock), or lodge into softer material (e.g., soil) on a semi-permanent basis. No scientific studies were found specific to this scenario relative to the Galapagos Islands; however, recovery following severe events (e.g., hurricanes, logging, and poor farming practices) in tropical regimes were studied in other parts of the world. These reports indicate that vegetation in moist to arid regimes would recover from these more severe conditions over a few years to decades, respectively (Mack, 1998; Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; and Donfack, 1995). In light of habitat recoveries in these extreme situations, and given the significantly smaller impact that could possibly occur during a failure of the Upper Stage, it may be inferred that any damage to the islands' habitats would be minor and short-term.

When a launch vehicle uses the 83.90° azimuth it directly overflies Cocos Island with the greatest dwell time (which is described as the amount of time the Upper Stage flies over the island). For this azimuth the potential for damage from surviving debris reaching Cocos Island is the greatest, however there is a probability of only 0.0000094 that damage would occur from a failed launch.

For Malpelo Island, there is a similar effect from the possibility of debris impacting the island environment. Azimuths of 82.6º to 85.07º and 86.36º to 97.4º are far enough away that ILLs for these flightpaths would not overlay the island. The 86.05º azimuth corresponds to the flight path with the greatest dwell time directly over Malpelo Island (i.e., 0.03 sec), and that corresponds to a probability of 0.0000019 that some debris might survive and fall on the island should there be a failure during Upper Stage flight.

For the Galapagos Islands—taken as a group—azimuths of 82.6º to 97.47º and 92.22º to 97.4º are far enough away so that ILLs for these flight paths would not overlay the islands or the 40-mile marine sanctuary surrounding the islands. The 90.85º azimuth corresponds to the flight path with the greatest dwell time (i.e., 10.61 sec) over several islands as well as inter-island water. This azimuth corresponds to a probability of 0.00067 that some debris might survive and fall on one of the Galapagos Islands or in the surrounding inter-island waters, should there be a failure during Upper Stage flight.

To provide some context to the remoteness of the probabilities being discussed above, the following probabilities have been reported (for U.S. citizens on an annual basis):

- the probability of a coal miner or farmer dying on the job is 0.0004,
- the probability of drowning is 0.00002,
- the probability of dying from a bicycle accident is 0.0000077, and
- the probability of being killed by lightning 0.0000005 (Laudan, 1994).

Debris Impacting South American Habitats

The probability of Upper Stage debris falling on South America (as well as a small portion of Panama) is very low. As indicated above, during a possible Upper Stage failure, approximately 42 components representing a combined surface area of 10 m^2 could survive reentry. Most debris would burn or vaporize in the atmosphere as it falls from an altitude of approximately 180 km (110 mi), and would, therefore, not affect either Central or South America. The surviving debris would be subjected to the intense heat generated while re-entering the upper atmosphere, and it would be hot to warm, having cooled during the descent through the lower atmosphere. As such, surviving debris would not present a fire hazard.

The probability of debris falling on Central or South America is related to the amount of time the Upper Stage is over the area, which varies with the azimuth of the launch, but ranges between 25 and 44 seconds[f] (see Table 4-7).

[f] These dwell times are associated with the heaviest anticipated payload (i.e., 6,100 kg or 13,420 lbs). Lighter payloads would result in shorter dwell times.

TABLE 4-7. UPPER STAGE AZIMUTHS OVER SOUTH AMERICA AND POPULATION CENTERS

Launch Azimuth (degrees)	Dwell Time for Continental overflight (sec)[	High Population[a] Density (per km^2)	Low Population Density (per km^2)	Cities Overflown (Populations Over 50,000)
083	25	207.22	0	Bucaramanga, Georgetown
084	27	207.22	0	Medellin, Puerto Ayacucho, Paramaribo
085	29	422.22	0	Pereira, Bogota, Cayenne
086	30	178.56	0	Buenaventura
087	30	44.30	0	Neiva, Boa Vista
088	32	44.30	0	Tumaco, Florencia
089	34	95.38	0	Esmeraldas, Ipiales, Mitú
090	37	131.16	0	Quito, Macapá
091	39	131.16	0	Manta, Portoveijo
092	40	211.47	0	Guayaquil, São Luís
093	39	874.36	0	Manaus, Fortaleza
094	43	88.14	0	Loja, Iquitos
095	44	117.55	0	Piura, Teresina, Mossoró
096	43	45.82	0	Imperatriz, Natal
097	42	289.72	0	Chiclayo, João Pessoa

[a] The data in Table 4-7 are calculated by using the 1^o x 1^o grid data from the *Carbon Dioxide Information Analysis Center* (CDIAC) database.

Though remote, the chance of damage to plants, animals or the habitat from falling debris would be due solely to the initial force of contact (e.g., a stricken animal or damaged vegetation). If debris falls on an animal, that animal could be injured or killed; however, the probability of such an event is estimated to be on the order of one in one million, or $1x10^{-6}$. The potential for long-term harm occurring to a regional habitat from falling debris would be minimal, and the recovery of damaged areas would occur through re-colonization by neighboring species or replacement by the larger population over a period of months or years.

Over much of the affected portion of South and Central America, the predominant ecosystem is tropical rain forest (see Figure 3-10). Since Upper Stage debris would at most cause a few isolated impacts (e.g., broken limbs) to widely spaced trees or similar foliage, recovery from such damage would occur relatively rapidly (i.e., on the order of months), although it may not completely return to pre-impact conditions for a number of years (Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; Mack 1998; Westy 2000; and Donfack, 1995). The majority of nutrients and natural resources in the tropical rain forest is typically found in the dense vegetation and canopy, and not in the soil. Any damage to the canopy or vegetation would affect these nutrients by temporarily removing them from the vegetative growth cycle, however these impacts are expected to be negligible. In the western lowlands and the more rocky mountainous areas of the continent, less vegetation is present to be damaged; however, recovery times would be much longer (i.e., several years or more) given the less fertile substrate and conditions for new growth. Nevertheless, any impact is expected to be negligible from this scenario on these receptors.

Debris Impacting Vessels, Aircraft, or Humans

An Upper Stage failure could also pose a small risk to vessels, aircraft, and humans. As described in Section 3.2.1.6 of this EA, shipping and aircraft traffic in the affected environment is relatively low, though traffic does increase closer to the coast of South and Central America. Conversely, the probability of Upper Stage debris falling on a vessel or aircraft diminishes as the Upper Stage approaches the coast of South America because as the altitude and speed of the Upper Stage increase, the impact window becomes smaller and more debris is burned up during descent.

The probability of debris from a mission failure falling on a person in an affected portion of Central and South America is also generally low and must satisfy FAA safety standards for SLLP to receive a license.[g] Based on the population densities calculated in Table 4-7, SLLP estimates the risk of debris falling on a person in the affected portions of Central and South America to be between 1.18×10^{-6} (corresponding to an 88° azimuth) and 3.26×10^{-6} (for a 93° azimuth).[h] The FAA has not yet conducted its review of SLLP's estimates for licensing purposes for the LOL. Although the FAA will be conducting a more detailed review of these estimates in its safety analysis through the licensing process, as estimates, they are considered the best information currently available, are not unreasonable and can be relied upon for the purposes of analyzing potential environmental impacts.

Summary of Possible Failure Scenarios and Impacts

Table 4-8 summarizes the possible failure scenarios and their potential environmental consequences.

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[g] The FAA's standard is based on the expected casualty rate (E_c), which is a function of dwell time, population density, and impact size. FAA's standards for an acceptable E_c is 30×10^{-6} or less.

[h] 1.18×10^{-6} corresponds to a chance of one in 847,000 of debris falling on a person, this is similar to the one-year odds of drowning in a bathtub. 3.26×10^{-6} corresponds to a chance of one in 306,000 of debris falling on a person, this is similar to the one-year odds of being struck and killed by a falling object.

TABLE 4-8. SUMMARY OF FAILURE SCENARIOS AND ASSOCIATED ENVIRONMENTAL IMPACTS

Failure Scenarios	Impact Area	Failure Rate	Potential Environmental Impacts
During initial Stage I Flight	Launch region	3×10^{-18}/sec (one in 30 trillion)	• ILV impacts open ocean virtually intact (Thrust Termination Failure), or in pieces (Explosive Failure) • Maximum quantity of propellants (e.g., kerosene) released and dispersed in the topmost ocean layer • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Stage I Flight	Downrange area of 800 km (500 mi)	26.94×10^{-5}/sec (one in 3,700)	• ILV (less most Stage I propellants) impacts open ocean after tumbling and fragmentation or explosion • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, residual reaching the topmost ocean layer (or combustion if Explosive Failure) • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Stage II Flight	Downrange area beyond 4,600 km (2,900 mi)	28.65×10^{-5}/sec (one in 3,450)	• Fragments of the ILV (less Stage I) surviving descent, impact open ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the topmost ocean layer • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Upper Stage Flight Over Ocean Waters	Downrange area beyond 4,600 km (2,900 mi) affecting shipping	6.28×10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage (ILV less Stages I and II) surviving descent, impact open ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the topmost ocean layer • Inert ILV fragments settle on ocean floor • Low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Upper Stage Fight Over an Oceanic Island	Potentially populated areas	6.28×10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems or shallow, near-island ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the ocean or land • Low probability of debris falling on vessels (fishing, shipping or air traffic) or on land or marine organisms
During Upper Stage Flight in vicinity of Panama Canal shipping	Western approaches to Panama Canal affecting shipping	6.28×10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems or coastal area • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the ocean or land • Low probability of debris falling on vessels (shipping) or land or marine organisms
During Upper Stage Flight Over South America	Potentially populated areas	6.28×10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach land • Low probability of debris falling on plants animals or people

4.1.3 Cumulative Impacts

Cumulative impacts to the environment result from incremental effects of the license applicant's proposed action or other alternatives when considered in combination with other past, present, and reasonably foreseeable future projects in the area. Cumulative impacts can result from minor, but collectively substantial, actions undertaken by various governments and U.S. agencies (Federal, state, and local) or by individuals. NEPA[i] requires the assessment of cumulative impacts resulting from all projects that are proposed, under construction, recently completed, or expected to be implemented in the near future.

With regard to the license applicant's proposed action and the corresponding affected environment, the Asia Pacific Space Centre has produced a Final Environmental Impact Study for the possible construction of a launch facility on Christmas Island (August 1999; Sinclair, Knight, Merz). However, the proposed facility has yet to be built and no launches have taken place. It does not appear that any specific dates have been set for future launches and such a possibility is not reasonably foreseeable. In addition, the FAA is not aware of any other past, present or reasonable foreseeable future projects in the area. Therefore, this EA focuses on the cumulative impacts associated with the proposed eight SLLP launches per year for five years, or a maximum of 40 launches, over the broader range of azimuths of the license applicant's proposed action. Section 4.6 of the February 11, 1999 EA evaluated the cumulative effects associated with up to six launches per year along a single azimuth. The February 11, 1999 EA concluded that SLLP operations at the proposed launch site, during launch, at the Home Port, and other connected actions including transport to and from the Home Port, would cause only insignificant and temporary impacts to the environment.

In general, all of the potential environmental impacts of the license applicant's proposed action would occur on a regional scale. No larger global impacts are expected to occur, mainly because of the small amounts of debris, hazardous material, and atmospheric emissions produced by the ILV relative to other anthropogenic activities (e.g., power generation and the scale of natural processes in the Pacific Ocean).

The potential cumulative effects for each phase of the launch operation are discussed below.

4.1.3.1 Home Port

The license applicant's proposed action differs from the February 11, 1999 EA in that it would involve eight launches per year. Other than the increase in the number of launches requiring processing, operations at the Home Port would be the same as those evaluated in the February 11, 1999 EA. The higher rate of throughput of both payload processing and marine vessel activity would remain within the capacity and regulatory approvals of all Home Port facilities, which were designed by SLLP to handle eight launches per year. Additional launches would generate more solid and hazardous waste material requiring disposal, although this increase may be offset by more efficient use of inventories (and less material being disposed of because it has expired). Home Port is allowed to store waste up to 90 days in its Central Hazardous Waste Accumulation area.

The Navy Mole facility, where the Home Port is located, is currently underutilized as compared to past levels of operation and development. The Navy Fuel Depot and the U.S. Department of Transportation Maritime Administration currently use the Navy Mole facility as well. It is planned that, in time, the former Navy facility will become part of the Alameda corridor, which is a rail transit system which moves containers from shipyards to railroad distribution points in Los Angeles. The additional launches would

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[i] This document is being developed based on the requirements of E.O. 12114, the implementation of which is guided by NEPA.

not place a significant burden on the Home Port's workforce or equipment; rather, the license applicant's proposed action would be expected to have a slight beneficial cumulative effect on socioeconomic conditions in the Home Port area through increased payrolls and material expenditures. Scrubber filters were installed at the Home Port facility to prevent UDMH vapors from escaping the building. Therefore, the license applicant's proposed action would have no adverse cumulative effects on the Home Port area.

4.1.3.2 Pre-Launch

Transit of the LP and ACS from Home Port to the launch site would be like any normal maritime shipping and would be subject to U.S., United Nations (UN), and other international rules and regulations. The vessels carry and must comply with the following certificates:

- Safety Construction Certificate (per International Convention for the Safety of Life at Sea (SOLAS), 1974, as modified by Protocol 1988),
- International Load Line Certificate (per International Convention on Load Lines, 1966 as modified by Protocol of 1988),
- International Oil Pollution Prevention Certificate (per International Convention for the Prevention of Pollution from Ships, 1973, as modified in Protocol 1978 and Resolution MEPC.39(29),
- Mobile Offshore Unit Safety Certificate (per Code for the Construction and Equipment of MODUs),
- Safety Equipment Certificate (per SOLAS 1974, as amended 1988),
- Certificate of Compliance for Prevention of Pollution by Sewage From Ships (per Annex IV of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by Protocol of 1978),
- Certificate of Compliance ILO No. 92 and 133 - Crew Accommodation (per International Labour Organization (ILO)), and
- International Tonnage Certificate (per International Convention of Tonnage Measurements, 1969).

The ships are further required to operate in compliance with the regulations of

1. The Government of The Republic of Liberia and carry the following certificates issued by Flag State:
    - Liberian Certificate of Registry
    - Liberian Ship Radio Station License
    - Liberian Minimum Safe Manning Certificate (per International Convention on Standards of Training, Certification and Watchkeeping, 1978, Resolution A.481(XII))
    - Liberian Special Purpose Ship Safety Certificate (per IMO Resolution A.534(13), Code of safety for Special Purpose Ships)
    - Liberian Self Propelled Mobile Offshore Unit Minimum Manning Scale for Marine Personnel

and

2. USCG Pollution Regulations Foreign Vessels, CFR Title 33 Part 155 and 159, and carry
    - Department of Transportation, USCG Vessel Certificate of Financial Responsibility (COFR), and
    - The State of California, Department. of Fish and Game, Certificate of Financial Responsibility.

The two additional round-trip transits by the ACS and LP per year would not contribute significantly to marine vessel traffic on the Pacific Ocean. Normal ACS ship wastes, including food waste, generated onboard are handled in accordance with the International Convention for the Prevention of Pollution (in compliance with MARPOL 73/78). All other solid waste is stored onboard and properly disposed of at the Home Port. Hazardous waste is accumulated onboard in hazardous waste accumulation areas and lowered to the pier at the Home Port when the vessels return. Waste is then taken to the Central

Accumulation Area and disposed of in accordance with local, state, and Federal regulations. Therefore, the proposed vessel operations would cause no significant cumulative effects.

Upon arrival at the launch location, pre-launch operations would only involve final equipment and process checks, coupling of propellant loading lines to the ILV, transfer of kerosene and LOX, and the decoupling of the loading lines. The only aspect of pre-launch operations that poses any potential environmental impact would be propellant loading of the ILV. However, standard propellant operations are expected to result in no loss of kerosene or LOX other than an incidental loss of vapors from the fluid connections, which would dissipate immediately. These propellants are volatile materials and any small amount released to the atmosphere would dissipate shortly thereafter resulting in no cumulative effects. LOX released to the environment during pre-launch loading would instantaneously vaporize upon being exposed to ambient pressure and temperature. Almost 95 percent of any kerosene released during pre-launch loading, which reaches the ocean, would evaporate within a few hours in the tropical conditions observed at the LP. The remaining 5 percent would be dispersed due to turbulence in the top few meters/feet of the ocean and then degraded to CO_2 and H_2O through photochemical oxidation and microbial degradation within days of the initial release (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). Accordingly, the ocean environment would return to pre-launch conditions within a day or so of these possible effects. Section 4.1.2.2 above discusses the impact of kerosene on marine communities.

In the open ocean, fish and marine mammals are not likely to be harmed by the small amount of kerosene released during pre-launch operations for several reasons:

- As mentioned above, SLLP would not initiate the launch if any whales or sea turtles were detected in the vicinity of the LP (during the visual observation period prior to launch).
- Relatively few fish or marine mammals are located in this region of the Pacific Ocean.
- Kerosene (in the amounts that would possibly be released during normal pre-launch operations) would disperse and degrade within hours of the release, which would minimize potential exposure to marine organisms until the next launch, in roughly 45 days.

Therefore, no cumulative effects are expected from this short term and highly localized impact. Based on the license applicant's proposed action, pre-launch operations would cause no cumulative impact.

4.1.3.3 Launch

Repeated launches over the Pacific Ocean present the potential for cumulative impacts, which may be one of two types:

- Effects of debris blown into the ocean, and
- Effects of heat and noise on marine mammals.

Potential Cumulative Effects of Debris Blown into the Ocean

The launch may blow some scattered debris into the ocean, although experience from SLLP launches to date has resulted in little to no material being lost. Should debris be lost, it would primarily be pieces of insulation or other hardware used to shield the LP during launch. The LP is continually hardened and improved to reduce the probability of such damage in the future. To date, only small, nonmetallic covers on the fairing vents have been lost to the ocean during launch. Because these material inputs would be small in volume and inert, they would sink to the ocean floor or otherwise cause little disruption or impact to the ocean ecosystem. Deck washing and repainting would not cumulatively affect the environment since this maintenance activity would occur on the deck of the LP with any waste put into containers for proper disposal at the Home Port. Although the increase in the number of flights would possibly result in more debris entering the ocean environment, the volume of material would remain very small relative to the scale of the east central Pacific Ocean.

Potential Cumulative Effects of Heat and Noise on Marine Mammals

The energy from heat and sound at launch would have only a momentary impact on the ocean, and would be dissipated within minutes, leaving no lasting or cumulative impact (see Section 4.1.1.2). In terms of heat, a freshwater spray would be used to reduce the energy and heat generated during the launch through evaporation. The ocean surface would deflect and absorb (through evaporation) any additional thermal energy. Increases in ocean temperature would be very localized, minimal, and of short duration with no significant adverse effects on marine organisms, which are primarily concentrated at some depth away from the intense tropical solar energy.

In terms of noise, the steady noise from pre- and post-launch operations (e.g., from ship engines) may reach approximately 70 dB. Research indicates, however, that this level of steady noise would not have a detrimental affect on any animal that would linger in the area (Shulhof, 1994; Richardson, et al., 1997). Each launch, in turn, would be a separate isolated incident lasting less than one minute, with approximately 45 days elapsing between events.

No significant noise impacts would be expected from the launch because of the relatively low level and short duration of launch noise, and the unlikely, continual presence of the higher trophic level organisms near the launch site. After each launch, the ambient noise levels and the local and transient biological communities would return to normal conditions within minutes. Accordingly, no cumulative effects are expected from this short term and highly localized impact.

4.1.3.4 Potential Cumulative Effects of Successful Flights Over the Open Ocean, Oceanic Islands, and South America

The potential cumulative effects of 40 successful flights over a five-year period would include:

- Spent stages and the fairing falling to the ocean,
- Residual propellants from the spent stages released to the ocean and atmosphere, and
- Emissions being released to the atmosphere.

It should be noted that although the license applicant's proposed action includes launches on a range of azimuths from 82.6º to 97.4º, actual flights would likely be along a narrower band of azimuths. Specifically, market forecasts indicate the majority of SLLP payloads would be medium-to-heavy geosynchronous earth orbit (GEO) satellites. Thus, SLLP customers would primarily want an equatorial or near-equatorial azimuth (within an approximate range of 88.5º to 91.5º) for their satellites.

Accordingly, cumulative impacts from successful missions for forecast manifests over the five years of the license applicant's proposed action have been assumed along a concentrated area of the open ocean (i.e., into smaller spent stage deposition areas especially along the equator) as the worst case. Since the EA considers launches within the full range of proposed azimuths the cumulative effects of impacts discussed in this section for successful missions are also applicable for any distribution of launches throughout the proposed range 82.6º to 97.4º. The cumulative impacts of successive failed missions are considered in Section 4.1.3.6.

Potential Cumulative Effects of Spent Stages and Fairing Debris, Including Hazardous Materials

Stage I, fairing, and Stage II debris from each launch would fall into the equatorial Pacific Ocean. Of all the potential cumulative impacts listed above for successful launches, the stage and fairing debris would be the only launch byproduct that would remain in the environment for a long period of time. Stage I would be expected to occasionally break up upon descent, while Stage II is expected to always break up during its descent from a high altitude. These objects would cool almost immediately upon reaching the water surface, and with the exception of the fairing pieces, would sink to the ocean floor immediately. The stage debris would be composed primarily of aluminum, steel, and graphite composite components, some incorporated with various plastic, ceramic, and rubber parts. These components are largely inert and would have no long-term direct effect on the ocean ecosystem. Fairing pieces are relatively large and solid but lightweight sheets of composite material. Based on the launch industry's experience with composite fairings, the two halves of the SLLP fairing would break up into a number of rigid pieces that would initially float, but gradually become waterlogged and eventually sink to the ocean floor.

From a cumulative impact perspective, the increase in the number of launches would introduce more debris into the equatorial Pacific Ocean in the debris deposition areas. The amount of this debris, however, is negligible when compared to the expanse of the equatorial Pacific Ocean. To evaluate cumulative impacts, a worst case scenario would be that all 40 launches over a five-year period would use the same azimuth. This hypothetical scenario further assumes that the deposited stage and fairing debris do not overlap (i.e., the flattened stage debris sinks to the bottom of the ocean without overlapping with previously deposited stage debris). In such a scenario, only 0.00015 percent of the ocean floor in the impact zones (see Table 4-1) would be affected by the 40 launches. Even with this hypothetical worst case scenario, the resulting impact to the regional seafloor would be insignificant.

In addition, the ocean depths in the Stage I, fairing, and Stage II impact zones are over 2,000 m (1.2 mi), where marine population densities are relatively low. This debris may potentially provide a benefit in the form of new habitat, which could harbor ocean-floor life forms in much the same way as sunken ships in nearshore areas provide new protective habitat for colonization (Chou, et al., 1991).

Potential Cumulative Effects of Residual Propellants Released from the Spent Stages to the Ocean and Atmosphere

The Stage I fuel tanks may rupture prior to impact with the ocean surface, while Stage II tanks would likely always rupture prior to impact. Any residual kerosene that leaks or is released from the tanks during descent would evaporate. The residual kerosene (up to 2,750 kg, or 6,050 lbs, or 760 gallons per mission) remaining in the Stage I fuel tanks that remain intact during descent, would be released to the ocean surface upon impact. For a maximum of eight launches per year, an annual total of 22,000 kg (48,400 lbs or 6,080 gallons) of residual kerosene would be released. Under worst-case conditions (i.e., assuming 40 launches over five years with all fuel tanks rupturing upon impact on the ocean surface), approximately 110,000 kg (242,000 lbs or 30,400 gallons) of residual kerosene would potentially be released to the open ocean. During each launch, the kerosene would evaporate and degrade relatively quickly. Specifically, almost 95 percent of any kerosene released from spent stages would evaporate and be dispersed as smog by reacting with solar energy. This smog would dissipate in the environment with little to no impact. The remaining kerosene on the ocean surface would be dispersed by turbulence in the top few meters of the ocean, and be degraded to CO_2 and H_2O through photochemical oxidation and microbial degradation within days of the initial release (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). Therefore, the release of kerosene will not result in a cumulative effect because it will evaporate and dissipate in the environment.

LOX released to the environment as the spent stages break up during descent or on the ocean surface would instantaneously vaporize upon being exposed to ambient pressure and temperature. Accordingly, the ocean environment would essentially return to pre-launch conditions within a few days and before the next launch would occur (45 days later under the license applicant's proposed action).

Section 4.1.2.2 discussed the impact of kerosene on marine communities. In the open ocean, fish and marine mammals would not likely be harmed by the small amount of kerosene released from the rupture of Stage I fuel tanks for several reasons:

- Relatively few fish or marine mammals are located in this region of the Pacific Ocean.
- Kerosene would disperse and degrade within hours to days of the release, which would minimize potential exposure to marine organisms until the next launch, in roughly 45 days.

Considering the recovery time of the marine environment following the particular impacts of any single successful launch (i.e., several days as discussed above), and the time between launches (on the order of 45 days), impacts from propellant reaching the ocean would be short term and not evident by the time the next launch would occur. Therefore, no significant cumulative impacts are expected from released propellants.

Potential Cumulative Effects of Emissions to the Atmosphere

The proposed launches would affect the atmosphere as the LV engines burn propellants, with the associated generation of gas, vapor, and particulate matter emissions. Further the passage of the ILV through the atmosphere will create a short-term hole in the atmosphere. Table 4-9 shows the propellant profile for an individual launch, the annual total fuel profile assuming eight launches per year, and the cumulative total propellant profile assuming 40 launches over five years.

TABLE 4-9. ILV PROPELLANT PROFILE*

Propellant	Single Launch (kg (lbs))	Annual Total (8 Launches) (kg (lbs))	5-Year Total (40 Launches) (kg (lbs))
LOX	304,577 (670,069)	2,436,616 (5,360,555)	94,464,640 (207,822,208)
Kerosene**	117,048 (257,505)	936,384 (2,060,045)	37,455,360 (82,401,792)
N_2O_4/MMH/UDMH	95 (210)	760 (1,672)	30,400 (66,880)

*Does not include payload propellants.
** Data on the various types of kerosene under consideration can be found in Appendix E.

Total annual and cumulative (i.e., from 40 launches) emissions by altitude are provided in Table 4-10. The transit time for the ILV to go from launch through the troposphere and stratosphere is 120 to 140 seconds. This transit time is the basis for determining emission quantities at various altitudes.

TABLE 4-10. TOTAL ANNUAL EMISSIONS FOR EIGHT LAUNCHES AND CUMULATIVE

Atmospheric Layer	**Altitude* Range (km (mi))**	**Annual Propellant Consumed (kg (lbs))**	**Annual Emission Products Assuming Eight Launches in kg (lbs)**				
			CO	**CO_2**	**H_2**	**H_2O**	**N_2**
Lower Troposphere	0.0-2.0 (0.0-1.2)	493,712 (1,086,166)	136,264 (299,781)	215,256 (473,563)	3,456 (7,603)	138,736 (305,219)	0
Free Troposphere	2.0-10.0 (1.2-6.2)	552,800 (1,216,160)	152,576 (336,667)	241,024 (530,253)	3,872 (8,518)	155,336 (341,739)	0
Stratosphere	10.0-51.0 (6.2-32)	1,270,648 (2,795,425)	350,696 (771,531)	554,000 (1,218,800)	8,896 (19,571)	357,056 (785,523)	0
Mesosphere and Thermosphere	51.0-292 (32-182)	997,576 (2,150,667)	271,896 (598,171)	444,064 (976,940)	7,928 (17,442)	273,808 (602378)	290 (640)
	Annual (8 Launches) Total	3,314,736 (7,248,418)	911,432 (2,009,156)	1,454,344 (3,199,110)	24,152 (53,134)	924,936 (2,034,859)	290 (640)
	Cumulative 5-Year (40 Launches) Total	16,573,680 (36,242,090)	4,557,160 (10,045,780)	7,271,720 (15,995,550)	120,760 (265,670)	4,624,680 (10,174,295)	1,450 (3,200)

* Altitude ranges are rounded to the nearest km.

Most emissions would be caused by operation of the Stage I and II engines; smaller quantities of Upper Stage and payload propellants would be expended beginning at approximately 112 km (70 mi) and 35,000 km (22,000 mi) into the flight, respectively, the latter occurring beyond the range of potential atmospheric impacts. During normal Stage I operation, the emissions would be distributed throughout the trajectory in the lower layers of the atmosphere. Stage I separation occurs at an altitude of approximately 70 km (44 mi). Releases from Stage II would occur well above the stratosphere (approximately between altitudes 70 to 190 km [43 to 118 mi]). In addition, emissions are likely to dissipate within a matter of days to weeks. Recently, a consolidated aerosol cloud was observed intact, nine to 12 days after a launch vehicle, using a kerosene-LOX propellant system, was launched in Central Asia (Newman, et al., 2001).

The chemical compounds released during any combustion are thought to contribute to several types of atmospheric environmental impacts, including global warming, acid rain, ozone layer destruction, and photochemical smog. Although CO_2 is a possible contributor to global warming, the amount released by the ILV is not significant compared with the estimated amount of CO_2 cycled at the ocean surface in this region.[j] Estimates of net annual CO_2 flux (from the ocean to the atmosphere) in the area of the launch site are one billion kg (2.2 billion lbs) per 1^{o} latitude/longitude square (Takahasi, et al., 1997). The 215,256 kg (473,563 lbs) predicted to be released annually by SLLP operations within the first two km of altitude represent an increase of 0.02 percent over natural emissions within the same 1^{o} latitude/longitude square. Solar convection mixes the CO_2 inputs from launch and natural sources such that the effect from launch emissions would be assimilated within hours, long before the next launch would occur.

Global warming and ozone depletion would be cumulative effects of the license applicant's proposed action (see Section 4.1.1.2). However, the contribution of these emissions is negligible when compared to

[j] In this region, the primary source of CO_2 is from the ocean air-water interface.

other global sources, natural or man-made. There do not appear to be any specific thresholds for CO_2 in this region and therefore, specific comparisons cannot be made between the potential cumulative effects of the license applicant's proposed action and local thresholds.

The greatest risk for adverse atmospheric impacts due to ILV emissions would be in the area of ozone layer destruction. The ILV does not release chlorine or chlorine compounds (which contribute to ozone destruction) in or below the stratosphere, and the SLLP impact in this regard would not be significant. While chlorine and chlorine compounds are not the sole contributors to ozone destruction - they are a major source because they are ozone destructors rather than simply acting as precursors to ozone depleting substances.

4.1.3.5 Post-Launch

After a successful launch, the crew would reoccupy and clean the LP in preparation for transit to the Home Port. The cleaning operation includes collecting any debris left on the LP, freshwater washing of residues (i.e., scorched, carbonized paint), and repainting the deck of the LP. This waste is put into containers and sent back to Home Port for proper disposal

Based on prior launch experience, little to no debris is typically left on the LP; this has included some damaged insulation that was used to protect equipment from the intense heat. Any debris would be collected and handled onboard as solid waste for later disposal at Home Port. The debris, at the maximum, would total approximately 50 kg (110 lbs) per year (assuming eight launches), or 250 kg (550 lbs) for the proposed five-year period (assuming a maximum of 40 launches). This amount of solid waste is insignificant and would not present any adverse cumulative effects as part of the overall waste stream managed when the vessels return to the Home Port.

4.1.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

From a cumulative impact perspective, the most significant adverse environmental effect associated with the license applicant's proposed action would be multiple launch failures in a single year along the same azimuth in close proximity to one another. In considering a scenario that would result in a worst-case cumulative impact, two consecutive failures that affect the same geographic area are evaluated. Considering more than two consecutive mission failures, however, is not a practical consideration since such a circumstance would severely challenge the continued viability of the SLLP launch concept.

Time Period Between Launches Following a Failure for An Investigation

Following a launch failure, for both commercial and safety reasons, launches would not resume until the cause of the failure is determined and corrected to the satisfaction of the FAA and SLLP. Considering multiple, successive failures as a hypothetical worst case, given the mandatory investigation process and for the reasons discussed below, the two successive failures would occur many months apart.

Any future SLLP mission failure would be followed by a mandatory FAA investigation lasting at least four and perhaps as much as 12 months before another mission would occur. The FAA conducted a failure investigation following the SLLP Mission 3 failure, which occurred on March 12, 2000. In this case the cause was established within 40 days and the entire investigation was completed within four months. This is atypical for the launch industry in which investigations can take up to 12 months to complete, with a return-to-flight occurring sometime later.

Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several failure scenarios that would affect different portions of the environment (i.e., the ocean, Oceanic Islands, Central or South America). These are discussed below.

Possible Failure Scenarios that could have Cumulative Effects on the Ocean

There are several possible failure scenarios that could cumulatively affect the ocean environment:

- Launch abort just prior to launch,
- Thrust termination failure, and
- Explosive failures.

A launch abort just prior to launch occurred during the SLLP Mission 6 launch planned for January 8, 2001. No hazardous materials or propellants were observed contacting the ocean surface and fewer emissions were released to the atmosphere than would occur under a successful launch because less of the propellant was combusted (see Section 4.1.2.1 for more detailed description). Therefore, this abort scenario would not have any significant direct or cumulative effects.

The thrust termination and explosion scenarios represent true mission failures and could possibly occur at the LP (explosive failure only) or at any point during Stage I, II, or Upper Stage flight over the ocean. Upper Stage failure could also occur over the Oceanic Islands or Central or South America and is described below. As analyzed in Section 4.1.2.2 above, thrust termination failure during the first 20 seconds of flight would likely result in the ILV falling intact and rupturing on the ocean surface thereby releasing nearly all of the ILV's propellants and hazardous materials directly to the ocean. This is considered the worst-case failure scenario. Of the explosive failure scenarios, an explosive failure at the LP would have the most significant effects on the ocean because there would be less time for combustion before the propellants and other hazardous materials would reach the ocean surface. Nevertheless, the environmental effects to the ocean of this scenario would still be less than a thrust termination early in flight because more of the propellants and hazardous materials would be consumed in the explosion and the LP provides some degree of protection for the ocean and would likely retain pieces of the ILV. Thrust termination failures later in flight would result in the ILV tumbling, breaking up due to stresses, and possibly exploding if flammable materials are exposed to hot engine parts during the fall. In either case (i.e., with or without an explosion), most of the propellants and other hazardous materials would either incinerate or evaporate before reaching the ocean surface with minimal effects on the ocean other than relatively inert materials settling on the ocean floor. Explosive failures at the LP or during Stage I, II, or Upper Stage flight would result in most of the ILV being consumed and most of the propellants and other hazardous materials being burned before reaching the ocean surface with minimal effects on the ocean other than relatively inert materials settling on the ocean floor.

Therefore, thrust termination failure early in flight is considered the worst-case scenario in terms of ocean effects and the cumulative effects of two consecutive thrust termination failures early in flight in close proximity to one another is addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.2 of this EA, which provides the technical basis and supporting references for the consideration of possible cumulative impacts.

Potential Cumulative Effects of Propellants and Other Hazardous Materials Released into the Ocean Under the Worst-Case Failure Scenario

Under the thrust termination failure early in flight scenario, the ILV would fall intact and rupture on the ocean surface. Nearly all of the ILV's propellants and other hazardous materials would remain unused and would be released directly to the ocean. This would include approximately 304,577 kg (670,069 lbs) of LOX, 117,048 kg (257,505 lbs) of kerosene, 95 kg (210 lbs) of N_2O_4/MMH/UDMH, and minor amounts of starting fluids (see footnote "d" on page 4-13 above). In the event of two successive thrust termination failures early in flight, the amount of propellants and other hazardous materials released into the ocean would double. However, the cumulative impacts are expected to be insignificant. For a discussion of the types and potential impacts of batteries used in the Zenit-3SL please refer to section 4.1.2.3 "Effects of Debris, Including Hazardous Materials in Open Ocean." The cumulative impacts are expected to be insignificant.

For a discussion of the impacts of releases of kerosene and LOX please refer to section 4.1.2.2 "Release of Hazardous Materials to the Ocean." No cumulative environmental impacts are expected due to releases to the ocean.

Recovery Timeframe

Even under the worst-case failure scenario, where the entire amount of propellants and other hazardous materials on the ILV are released directly to the ocean, the ocean environment would recover to natural conditions within a week. The subsequent launch, accounting for the required investigation, would not occur for four to 12 months. The elapsed period of four to 12 months would provide more than sufficient time for the ocean environment to recover, even if the subsequent launch results in a thrust termination failure early in flight and the ILV impacts the same area of the ocean surface. Therefore, no cumulative impact to the ocean environment would occur as a result of two successive, worst-case failures, even those that happen to affect the same area of the ocean.

Potential Cumulative Effects on the Oceanic Islands or South American Landmasses Under the Worst-case Failure Scenario

The Oceanic Islands and Central or South America could only be affected by a possible failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). A possible Upper Stage failure could be the result of either thrust termination or explosion. As discussed below, both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of potential cumulative impacts to the Oceanic Islands or Central or South America. The cumulative effects of two consecutive Upper Stage failures that strike the Oceanic Islands or Central or South American landmasses in close proximity to one another are addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts.

Potential Cumulative Effects of Propellants and Other Hazardous Materials Released Onto Landmasses

A failure during Upper Stage flight would result in most of the ILV components and all of the propellants and other hazardous materials being heated in the atmosphere and vaporized or burned from frictional effects before reaching the Earth's surface because of the speed and altitude of the Upper Stage during this period of flight. Approximately 42 components from the Upper Stage and payload would survive reentry friction and reach the Earth's surface (see Table 4-5). These objects range from 0.04 m (0.13 ft) to 1.2 m (3.9 ft) and total approximately 10 m^2 in size. Potential cumulative impacts from releases resulting from an Upper Stage failure would be insignificant.

Recovery Timeframe

As described above, the only effects of an Upper Stage failure on the Oceanic Islands or Central or South American landmasses would be from the components that survive reentry. These components would be inert after being subject to the intense heat generated while re-entering the upper atmosphere. The surviving components, which would cool during the descent through the lower atmosphere, would still be initially hot to warm, but would not pose a risk of fire. Therefore, the only potential cumulative effects from the components would be the physical damage associated with striking terrestrial plant or animal species.

If debris struck an animal, it could be injured or killed. There is an extremely remote chance that a threatened or endangered species could be hit by falling debris. Should such harm occur, replacement in terms of population dynamics would depend on the individual species' abundance, reproduction characteristics, and recruitment success.

No scientific studies were found specific to this scenario, however, recovery following severe events (e.g., hurricanes, logging, and poor farming practices) in tropical regimes have been studied. These reports indicate that vegetation in moist regimes would recover from these more severe conditions over a few years to decades, respectively (Mack, 1998; Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; and Donfack, 1995). In light of habitat recovery times in these extreme situations, and given the significantly smaller impact that could possibly occur during a failure of the Upper Stage, it may be inferred that any damage to the islands' habitats would be minor, but could require some period of time to fully recover.

Recovery time would be relatively long in this scenario as compared with the ocean environment, and any damaged or injured plants or animals may not recover by the time of the subsequent launch (assuming four to 12 months for the failure investigation). Assuming that the subsequent launch also fails and that the surviving components strike approximately the same portion of the Oceanic Islands or Central or South American landmasses, there would be additional incremental injury to the plant or animal or the local ecosystem.

These additional cumulative impacts, however, would likely be minor, with the exception of any endangered species that may be hit. The probability of these components falling on the Galapagos Islands, for example, is very low (0.00067, see Table 4-6), and the probability of striking an endangered species would be even more remote.

Although an injured individual or ecosystem population may not have had the time to return to pre-event conditions, the incremental damage caused by the second event would marginally prolong recovery time for that species or for the ecosystem as a whole. For example, a delay of six months between two launches that end in failures that cause physical damage to exactly the same area in a rain forest would, in effect, add approximately six months to the time it would take for that rain forest community to recolonize the damaged area. Accordingly, cumulative effects following two successive, worst-case failures affecting the same area would only marginally delay the recovery process. In this hypothetical case, the second impact would double the affected area, marginally prolonging the recovery of the first or second impact due to the corresponding impairment of neighboring habitat that would otherwise facilitate recovery through recolonization (i.e., reestablishment of floral or faunal colonies). However, the likelihood of such events occurring is extremely small.

4.1.4 Other Environmental Concerns

4.1.4.1 Environmental Justice

Although E.O. 12114 requires consideration of Federal actions abroad with the potential for impacts to the environment, the Executive Order specifically defines environment as "the natural and physical environment and excludes social, economic and other environments…." Therefore, potential impacts to environments other than the natural and physical are not analyzed in this document. Nevertheless, given the limited amount of time that the LP and the ACS will be present at the launch location, social and economic considerations are assumed to be negligible.

4.1.4.2 Exclusive Economic Zones

Under successful flight conditions, any potential environmental impact from the stages and fairing would occur outside the EEZ—defined as 200 nautical miles (370 km or 230 statute miles) of all countries bordering the affected environment. (Table 4-2 lists the closest expected distances between stage and fairing impacts to the nearest land areas.) Only in the event of a mission failure during Upper Stage flight would the deposition of debris potentially occur within an EEZ. Potential environmental impacts of such an occurrence are discussed in Section 4.1.2.3. As with all mission failures, an intensive investigation as to the cause of the failure would be completed. A return to flight for the SLLP project would be re-instated only after corrective actions are undertaken to the satisfaction of the FAA and SLLP.

4.1.4.3 Social and Economic Considerations

Although E.O. 12114 requires consideration of Federal actions abroad with the potential for impacts to the environment, the Executive Order specifically defines environment as "the natural and physical environment and excludes social, economic and other environments…." Therefore, potential impacts to environments other than the natural and physical are not analyzed in this document. Nevertheless, under the license applicant's proposed action SLLP would occupy the launch location for two to seven days during each launch cycle (or up to 56 days per year). For each launch, the LP and ACS sail directly to the launch location and return directly to the Home Port. The relatively brief duration of activity and the relative degree of isolation of the launch location provide an effective barrier between the license applicant's proposed action and the social, economic, and cultural character of Kiribati society. Since there would be no significant interaction with Kiribati society, the presence of the ACS and LP for up to 56 days per year at the launch site would have no significant social or economic effects.

The license applicant's proposed action would have no effect on the social or economic conditions of the Galapagos Islands, Cocos Island, or Malpelo Island, or that portion of South America that lie under the flight path as for successful launches, the ILV would simply fly over these areas and would have no beneficial or adverse effects. Under the mission failure scenarios, only a failure during the Upper Stage would have any effect on the Oceanic Islands or Central or South America, and this would be limited to the few fragments of the Upper Stage and payload that would not burn up or vaporize in the atmosphere. The deposition of this debris on the Oceanic Islands or Central or South America would have no significant effect on social or economic conditions.

4.2 ENVIRONMENTAL EFFECTS OF ALTERNATIVE WITH AVOIDANCE OF THE OCEANIC ISLANDS

This section of the EA evaluates the environmental effects of the alternative to the license applicant's proposed action in which the Oceanic Islands are avoided. Under this alternative, only azimuths between 82.60º to 83.28º, 84.50º to 85.07º, 86.36º to 88.80º and 92.89º to 97.4º would be used. While the environmental impacts described in Section 4.1 would largely apply, a different analysis would apply in regard to the Oceanic Islands and the corresponding portions of South American continent, which would not be overflown in this alternative action.

The evaluation of this alternative uses the same operational phases and actions (i.e., Home Port, pre-launch, launch, successful flight, post-launch and possible failure scenarios) to frame the discussion as those identified in Section 4.1. Where discussions of impacts are identical to those for the license applicant's proposed action the reader is referred to that section to avoid redundancy.

4.2.1 Environmental Effects of Successful Flight

4.2.1.1 Home Port

The impacts to Home Port from this alternative are the same as those discussed in Section 4.1.1.1.

4.2.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

The impacts to pre-launch, launch, and Stage I and II flight over open ocean from this alternative are the same as those discussed in Section 4.1.1.2.

4.2.1.3 Upper Stage Flight Over South America

Upper Stage and payload flight would progressively transit over open ocean waters and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes. Launch impacts from this alternative are the same as those discussed in Section 4.1.1.3.

4.2.1.4 Post-Launch Operations

The impacts of post launch operations from this alternative are the same as those discussed in Section 4.1.1.4.

4.2.2 Environmental Impacts of Possible Failed Mission Scenarios

The impacts of possible failed mission scenarios from this alternative are the same as those discussed in Section 4.1.2, except for potential impacts to Oceanic Islands which would be avoided.

4.2.2.1 Failure at the Launch Platform Scenario

The impacts of failure at the launch platform from this alternative are the same as those discussed in Section 4.1.2.1.

4.2.2.2 Failure During Stage I and II Flight Over Open Ocean Scenario

The impacts of failures during Stage I and II flight from this alternative are the same as those discussed in Section 4.1.2.2.

4.2.2.3 Failure During Upper Stage Flight Over the Ocean or South America Scenario

The impacts of failure during Upper Stage flight for this alternative would be the same as those discussed in Section 4.1.2.3 with the exception that no impact would occur on or near the Oceanic Islands.

Summary of Failure Scenarios and Impacts

Table 4-8 summarizes the estimated types of failures and their consequences for several different failed mission scenarios.

4.2.3 Cumulative Impacts

The potential cumulative impacts from this alternative are the same as those discussed in Section 4.1.3.

4.2.3.1 Home Port

The potential cumulative impacts to the Home Port facility from this alternative are the same as those discussed in Section 4.1.3.1.

4.2.3.2 Pre-Launch

The potential cumulative impacts of pre-launch operations from this alternative are the same as those discussed in Section 4.1.3.2.

4.2.3.3 Launch

The potential cumulative impacts of launch operations from this alternative are the same as those discussed in Section 4.1.3.3.

4.2.3.4 Successful Flight Over the Open Ocean and South America

The potential cumulative impacts of successful flights over the open ocean and South America from this alternative are the same as those discussed in Section 4.1.3.4. The exception is that no potential cumulative impact would occur on or near the Oceanic Islands.

4.2.3.5 Post-Launch

The potential cumulative impacts of post-launch operations from this alternative are the same as those discussed in Section 4.1.3.5.

4.2.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

The potential cumulative impacts of multiple launch failures in a single year in the same area from this alternative are the same as those discussed in Section 4.1.3.6.

Possible Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several failure scenarios that would affect different portions of the environment (i.e., the ocean, and Central or South America). These are discussed below.

Possible Failure Scenarios Affecting the South American Landmass

Central or South America could only be affected by a failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). An Upper Stage failure could be the result of either thrust termination or explosion. Both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of impacts to Central or South America. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts. The potential cumulative impacts of launch operations from this scenario are the same as those discussed in Section 4.1.3.6.

4.2.4 Other Environmental Concerns

4.2.4.1 Environmental Justice

The impacts on environmental justice from this alternative are the same as those discussed in Section 4.1.4.1.

4.2.4.2 Exclusive Economic Zones

The impacts on exclusive economic zones from this alternative are the same as those discussed in Section 4.1.4.2.

4.2.4.3 Social and Economic Considerations

See Section 4.1.4.3.

4.3 ENVIRONMENTAL EFFECTS OF ALTERNATIVE WITH AVOIDANCE OF THE GALAPAGOS ISLANDS

This section of the EA evaluates the potential environmental effects of the alternative to the license applicant's proposed action in which the Galapagos Islands are avoided. Under this alternative, only azimuths between 83.60º to 86.80º, and 92.89º to 97.40º would be used. While the environmental impacts described in Sections 4.1 and 4.2 above would largely apply, a different analysis would apply in regard to Galapagos Islands and the corresponding portions of the South American continent, which would not be overflown under this alternative action.

The evaluation of this alternative uses the same operational phases and actions to frame the discussion as were identified in Section 4.1 for the license applicant's proposed action. The reader will be directed to the relevant section in this EA.

4.3.1 Environmental Effects of Successful Flight

4.3.1.1 Home Port

The impact to Home Port from this alternative will be the same as those discussed in Section 4.1.1.1.

4.3.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

The impact to pre-launch, launch, and Stage I and II flight over open ocean from this alternative will be the same as those discussed in Section 4.1.1.2.

4.3.1.3 Upper Stage Flight Over the Oceanic Islands and South America

Upper Stage and payload flight would progressively transit over open ocean waters, the Oceanic Islands (excluding the Galapagos Islands), and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes. Launch impacts from this alternative are the same as those discussed in Section 4.1.1.3.

4.3.1.4 Post-Launch Operations

The impacts of post launch operations from this alternative are the same as those discussed in Section 4.1.1.4.

4.3.2 Environmental Impacts of Possible Failed Mission Scenarios

The impacts of possible failed mission scenarios from this alternative are the same as those discussed in Section 4.1.2, except for potential impacts to the Galapagos Islands which would be avoided.

4.3.2.1 Possible Failure at the Launch Platform

The impacts of possible failure at the launch platform from this alternative are the same as those discussed in Section 4.1.2.1.

4.3.2.2 Possible Failure During Stage I and II Flight Over Open Ocean

The impacts of possible failures during Stage I and II flight from this alternative are the same as those discussed in Section 4.1.2.2.

4.3.2.3 Possible Failure During Upper Stage Flight Over the Ocean, Oceanic Islands (excluding the Galapagos Islands), or South America

The impacts of possible failure during Upper Stage flight for this alternative would be the same as those discussed in Section 4.1.2.3 with the exception that no impact would occur on or near the Galapagos Islands.

Summary of Possible Failure Scenarios and Impacts

Table 4-8 summarizes the estimated types of failures and their consequences for several different possible failed mission scenarios.

4.3.3 Cumulative Impacts

The potential cumulative impacts from this alternative are the same as those discussed in Section 4.1.3.

4.3.3.1 Home Port

The potential cumulative impacts to the Home Port facility from this alternative are the same as those discussed in Section 4.1.3.1.

4.3.3.2 Pre-Launch

The potential cumulative impacts of pre-launch operations from this alternative are the same as those discussed in Section 4.1.3.2.

4.3.3.3 Launch

The potential cumulative impacts of launch operations from this alternative are the same as those discussed in Section 4.1.3.3.

4.3.3.4 Successful Flight Over the Open Ocean, Oceanic Islands (excluding the Galapagos Islands), and South America

The potential cumulative impacts of successful flights over the open ocean Oceanic Islands excluding the Galapagos Islands and Central and South America from this alternative are the same as those discussed in Section 4.1.3.4.

4.3.3.5 Post-Launch

The potential cumulative impacts of post-launch operations from this alternative are the same as those discussed in Section 4.1.3.5.

4.3.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

The potential cumulative impacts of multiple launch failures in a single year in the same area from this alternative are the same as those discussed in Section 4.1.3.6.

Possible Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several possible failure scenarios that would affect different portions of the environment (i.e., the ocean, Cocos or Malpelo Island, South America).

Possible Failure Scenarios Affecting Cocos Island, Malpelo Island, or South American Landmasses

The Cocos and Malpelo Islands and Central and South America could only be affected by a failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). A possible Upper Stage failure could be the result of either thrust termination or explosion. As discussed below, both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of Cocos and Malpelo Islands or Central or South American effects. The cumulative effects of two consecutive Upper Stage failures that strike the Cocos and Malpelo Islands or Central or South American landmass in close proximity to one another is addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts.

Possible Cumulative Impacts of Propellants and Other Hazardous Materials Released Onto Landmasses

For a discussion of the possible cumulative impacts of propellants released onto landmasses please refer to Section 4.1.3.6 "*Potential Cumulative Effects of Propellants and Other Hazardous Materials Released onto Landmasses*" with the exception that no impact would occur on or near the Galapagos Islands.

4.3.4 Other Environmental Concerns

4.3.4.1 Environmental Justice

See Section 4.1.4.1.

4.3.4.2 Exclusive Economic Zones

The impacts on exclusive economic zones from this alternative are the same as those discussed in Section 4.1.4.2.

4.3.4.3 Social and Economic Considerations

See Section 4.1.4.3.

4.4 NO ACTION ALTERNATIVE

Under the No Action alternative FAA would not issue the LOL to SLLP for eight launches per year for five years, for azimuths ranging from 82.6º to 97.4º or the launch specific license for a 90º launch of the Galaxy IIIC. SLLP would continue to prepare and submit launch-specific applications for individual licenses to launch up to six satellites per year within the launch parameters analyzed in the February 11, 1999 EA. Home Port operations would continue at their present level. If a customer required a different launch azimuth, SLLP would prepare individual environmental analyses and documentation (to support launch-specific applications) for each launch.

The launch-specific application and license process would be repeated approximately every 60 days, as warranted by commercial demand.

4.5 SUMMARY OF ENVIRONMENTAL IMPACTS FOR LICENSE APPLICANT'S PROPOSED ACTION AND ALTERNATIVES

Table 4-11 provides a brief summary of the potential environmental impacts associated with the license applicant's proposed action and reasonable alternatives including no action. Table 4-11 provides a brief summary comparing the license applicant's proposed action and alternatives.

TABLE 4-11. POTENTIAL ENVIRONMENTAL EFFECTS OF THE LICENSE APPLICANT'S PROPOSED ACTION ON THE ATMOSPHERE, OPEN OCEAN, OCEANIC ISLANDS, AND SOUTH AMERICA

		License Applicant's Proposed Action	Alternative with No Oceanic Island Overflight	Alternative with Avoidance of Galapagos Islands	No Action
	Probability of Effect[k]	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**
Atmosphere					
Release of residual propellants (kerosene, LOX)	Unavoidable[l]	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Release of combustion emissions (CO, CO_2, H_2, and H_2O)	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Open Ocean					
Debris deposition[m]	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Release of residual propellants into ocean	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA

[k] In Table 4-11, the column titled "Probability of Effect" refers to the likelihood of the potential effect occurring.

[l] In this instance, unavoidable effects refer to those impacts that will occur because they are part of the normal operations.

[m] In this instance, debris refers to jettisoned spent stages that are part of the normal operations of expendable launch vehicle launches.

		License Applicant's Proposed Action	Alternative with No Oceanic Island Overflight	Alternative with Avoidance of Galapagos Islands	No Action
	Probability of Effect	Potential Environmental Effects	Potential Environmental Effects	Potential Environmental Effects	Potential Environmental Effects
Injury or mortality of marine organisms from heat and noise associated with launch	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Injury or mortality of marine organism from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Oceanic Islands					
Damage to terrestrial habitat/vegetation from impact with falling debris	Unlikely	Insignificant	None	Probability of impact is slightly lower than license applicant's proposed action (reduced by 0.00067)	Same as impacts in February 11, 1999 EA
Injury or mortality of terrestrial organism from impact with falling debris	Unlikely	Insignificant	None	Probability of impact is slightly lower than license applicant's proposed action (reduced by 0.00067)	Same as impacts in February 11, 1999 EA
Damage to coral reef communities from impact with falling debris	Unlikely	Insignificant	None	Approximately the same as license applicant's proposed action since majority of coral reefs surround Cocos Island and not the Galapagos	Same as impacts in February 11, 1999 EA

		License Applicant's Proposed Action	Alternative with No Oceanic Island Overflight	Alternative with Avoidance of Galapagos Islands	No Action
	Probability of Effect	Potential Environmental Effects	Potential Environmental Effects	Potential Environmental Effects	Potential Environmental Effects
South America					
Damage to terrestrial habitat/vegetation (i.e., rain forest) from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Damage to commercial vessel or aircraft or injury or mortality of human from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA

4.6 ENVIRONMENTAL MONITORING AND PROTECTION PLAN (EMPP)

The EMPP is an evolving document, incorporating improvements approved by the FAA, including those identified by the FAA or SLLP, or those recommended by public reviewers (see Appendix G of this document for the current EMPP). The plan consists of four elements:

- Visual observation for species of concern.
- Remote detection of atmospheric effects during launch.
- Collection of surface water samples to detect possible launch effects.
- Notification to mariners and air traffic.

By reviewing EMPP reports, for example, the FAA determined that more specific visual observation training of personnel was required. Additional training was conducted and improvements in this area continue to be evaluated periodically. Similarly, the water sampling processing has undergone changes to improve the accuracy of results. SLLP has implemented a three pre-launch and nine post-launch water sampling method in which samples are taken on points on a grid located down-current from the LP and positioned to intercept waters flowing past the LP, as estimated by the set and drift of the surface current. Additionally, SLLP and FAA are currently evaluating automated water sampling equipment and photometering equipment to determine if their use would improve the accuracy of results while maintaining the required level of safety for onboard crew. Nighttime water sampling occurred once but it was determined to pose an unacceptable safety risk to the crew. The notification process for mariners and air traffic has also been refined, as feedback to prior notices has been collected.

As part of SLLP's ongoing EMPP program, crew members have made visual observations for species of concern. Sightings have included sharks, tuna, dorado, and gulls, all not included as species of concern. The only species of concern (as listed in the EMPP) to be sighted to date was one Hawaiian Dark-Rumped Petrel, sighted on the fourth launch.

Also as part of SLLP's ongoing EMPP program, crew members have taken samples of the downstream surface water within 30 minutes of launch to analyze for the presence of kerosene on the ocean surface. For six of the seven launches to date water sampling has been conducted (water sampling was not conducted during one night launch for safety reasons). The chemical analysis for each of these samples (three pre-launch and nine post-launch) has returned a result of "no detection" for kerosene. Sampling methods are being reviewed to improve the ability to capture possible contaminant releases during the pre- and post-launch period.

Under the EMPP, SLLP collects video- and radar-scan data on atmospheric effects of each launch. Data are available for three of the four launches to date. Visible plumes were recorded on two of the launches; night conditions and low-cloud cover prevented video scans for the other two launches. The results of the scans for the fourth mission, by way of example, are discussed below.

A visible plume associated with the launch was sighted between 61 and 72 seconds after launch. This equates to the base of the plume beginning at approximately 13.5 km (8.4 mi), and the top of the plume ending at 18.4 km (11.5 mi) above sea level. In the tropics, a layer of High Altitude Tropical (HAT) cirrus clouds (ice crystals) extends about 3 to 5 km (1.9 to 3.1 mi) below the tropopause. The HAT cirrus clouds are occasionally visible; at other times, the concentration of ice crystals is not sufficient to be visible to the naked eye. Based on data SLLP obtained from a weather balloon released 40 minutes before the launch, the base of the tropopause was at approximately 16.2 km (10.1 mi) at the time of launch. The base of the ILV contrail was thus observed approximately 2.7 km (1.7 mi) below the tropopause base.

As the ILV plume, which is rich in water vapor, transits the lower layer of the HAT, ice crystals form in the water vapor of the plume and mix with existing ice crystals. The increased concentrations of ice crystals make the contrail visible. This process involves the same mechanism that generates airplane contrails. As the ILV transitions into the stratosphere, where ambient moisture is practically nonexistent, ice crystal formation is dramatically reduced and the contrail abruptly terminates at about 18.4 km (11.5 mi).

C-Band Doppler weather radar scans have generated data for three of the four launches. The radar scan is used to determine the presence of particles within the nonvisible spectrum. No particles were detected in the second and third launches. In the first launch particles were detected with a density reading of 5 particles per cubic centimeter (cm^3); however, because no visible plume was detected at the same time, it is hypothesized that the particles were less than 1mm in diameter. It is further hypothesized that this concentration of particles was possible only with the aid of external atmospheric features. In fact, a significant wind-shear was detected at the launch site at an 8-km (5 mi) altitude from this analysis.